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THE COMPRESSIBLE LAMINAR BOUNDARY LAYER WITH HEAT TRANSFER ON A YAWED CONE AT SMALL ANGLE OF ATTACK

by

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ABSTRACT

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A perturbation method for the calculation of velocity and temperature profiles and skin-friction and heat transfer coefficients is presented for the flow in the compressible laminar boundary layer about a yawed cone in a supersonic stream. Both insulated and noninsulated surfaces are considered.

Numerical solutions of the governing differential equations are given in terms of universal functions which are tabulated for Prandtl numbers of 0.72 and 1.00. Theoretical heat transfer rates are compared to existing experimental data.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	Coefficient defined in Equation (52)
A_2	Coefficient defined in Equation (34)
B	Coefficient defined in Equation (5b)
B_2	Coefficient defined in Equation (34)
C	Temperature - Viscosity law constant
C_p	Specific Heat at constant pressure
C_{fx}	Meridional component of skin friction
$C_{f\phi}$	Circumferential component of skin friction
D	Coefficient defined in Equation (5d)
D_2	Coefficient defined in Equation (34)
E	Internal energy
f	Function defined in Equation (21b)
$f_{21},\ldots,f_{24}$	Universal functions for heat transfer case
$\tilde{f}_{21},\ldots,\tilde{f}_{23}$	Universal functions for insulated wall case
F	Function defined in Equation (17d)
g	Function defined in Equation (21c)
$g_{21},\ldots,g_{23}$	Universal functions for heat transfer case
$\tilde{g}_{21}$, $\tilde{g}_{22}$	Universal functions for insulated wall case
G	Function defined in Equation (17e)
h	Enthalpy

h	Heat transfer coefficient
k	Mangler Transformation constant
M	Mach number
Nu	Nusselt number
p	Pressure
P_2	Coefficient defined in Equation (5c)
Pr	Prandtl Number
q	Heat transfer rate
r	Radius of cone section
R	Gas constant
Re	Reynolds number
$s = S$	Dimensionless coordinates
S'	Sutherland's constant for air
T	Static temperature
u	x - component of velocity
v	y - component of velocity
w	ϕ - component of velocity
x	Coordinate along cone ray
X	Howarth Transformed x coordinate
y	Coordiante normal to cone surface
Y	Howarth Transformed y coordinate
α	Angle of attack
γ	Ratio of specific heats

ε	Perturbation parameter defined in Equation (25)
η	Mangler Transformed Y coordinate
θ	Defined as $\sin\theta_c$
θ_c	Cone Semi-vertex angle
λ	Blasius similarity variable
κ	Coefficient of thermal conductivity
μ	Coefficient of viscosity
ξ	Mangler Transformed x coordinate
ρ	Density
τ	Skin friction
ϕ	Circumferential cone angle
Φ	Component of vector potential
Ψ	Component of vector potential

Subscripts

aw	Adiabatic wall condition
e	Local conditions at the edge of boundary layer
w	Wall value
1	Conditions at zero angle of attack
2	Conditions at angle of attack
∞	Condition in undisturbed flow
	Subscript notation for partial differentiation

is used where convenient

Superscripts

*	Denotes nondimensional quantities, according to Equation (12)
'	Primes denote ordinary differentiation
—	Barred quantities denote evaluation at the cone surface in the inviscid flow field at zero angle of attack

I. INTRODUCTION

The compressible laminar boundary layer on a yawed circular cone in supersonic flow has been the object of several investigations. One reason for this is that the circular cone is a good approximation for the nose portion of a pointed supersonic aircraft fuselage or missile. It is thus desirable to have some knowledge of the flow field and heat transfer rates about a yawed cone to help in design considerations of such bodies. Therefore this report will consider both the flow field and heat transfer associated with the laminar boundary layer of a cone at small angles of attack.

F. K. Moore (Ref. 1) was the first to develop the governing equations applicable to the compressible laminar boundary layer about a general conical body in supersonic flow. In that report Moore considered the boundary layer equations in implicit co-ordinates and applied Howarth-Mangler and similarity transformations to obtain a form of the boundary layer equations applicable to cones in supersonic flow. Using these governing equations he then considered the case of an insulated cone with a Prandtl number of one. In reference 2, Moore employed a perturbation analysis about zero angle of attack to find solutions to the governing equations for small angle of attack. These solutions may be applied around the entire cone. For cones at large angle of attack he obtained exact solutions to the set of non-linear ordinary differential equations (Ref. 3). However, these solutions are restricted to the plane of symmetry. For large angles

of attack the analysis failed to give unique solutions on the leeward side of the cone. Beyond a certain angle of attack, the boundary layer flow no longer existed in the plane of symmetry possibly indicating the occurence of separation.

Reshotko (Ref. 4) relaxed the condition of an insulated cone for the large angle of attack case, and consequently determined the heat transfer rates to the cone along the windward streamline in the plane of symmetry.

Nowlan (Ref. 5) extended the analysis of Reshotko to treat the boundary layer along rays of the cone other than in the plane of symmetry. Hence, in this case, the cross flow velocity need not be zero. He found numerical solutions to the governing equations for small angles of attack which agreed well with experimental data to a point. For larger angles of attack Nowlan was not able to obtain solutions around the entire cone.

The purpose of this study is to generalize the solutions obtained by Moore (Ref. 2) for the cone at small angle of attack by removing the restrictions of insulated surfaces and unit Prandtl number. The solutions are obtained by a perturbation in angle of attack about the zero angle of attack solutions for the cone. Although the theory applies for any constant Prandtl number, the numerical solutions are limited to Prandtl numbers of 0.72 and 1.00. Also, for the case of heat transfer, results are limited to constant wall temperatures for the cone. The insulated and heat transfer problems are treated separately, and the solutions for each are presented in tabular form so

that for a particular application the work is reduced to arithmetic combinations of the tabulated values. In reference 4, it is reported that G. M. Low completed an analysis equivalent to the one presented herein. That study was never published and is presumed lost.

II. DERIVATION OF GOVERNING EQUATIONS

II. 1 Coordinate System

This report considers the flow of a viscous, compressible, heat conducting fluid over a circular cone. For a fluid of small viscosity (e.g. air) it is known from observation that when the fluid flows past a solid surface there is a thin layer where the velocity of the fluid undergoes a rapid change from the surface value to that associated with the inviscid steam flowing past the object. In this layer the viscous and inertia forces are of comparable magnitude due to the fact that the space rate of change of the shearing stresses may be very large. Using such an argument to order the equations of motion, the boundary-layer equations can be obtained.

Since Moore in reference 1 presented the development of the compressible laminar boundary layer equations for a conical body in a definitive manner, most of the following formulation will be guided by his analysis.

Because a circular cone is a developable surface (i.e., one that can be rolled out into a plane without stretching) it is possible to define the governing equations in Cartesian form on the geodesics of the surface. Verification of this by Mager can be found in reference 6.

For the circular cone the geodesics are the rays and the circles in planes normal to the cone axis. Thus we can define the

following orthogonal coordinate system:

1. The body surface is defined by y = 0

2. A point is defined by the coordinates x, y, r(x)s

where x is the distance along a ray of the cone, y is the distance normal to the cone surface, s is a dimensionless angular coordinate, and r(x) the radius of a cross-section of the cone (see figure 1).

For a circular cone we have

$$r(x) = x\Theta \qquad \Theta \equiv \sin\theta_c \tag{1}$$

In this system then, if the velocity components are u, v, and w in the x, y, and s directions respectively, the compressible laminar boundary layer equations for a steady flow of an ideal gas are

CONTINUITY

$$\frac{\partial}{\partial x}(\rho r u) + \frac{\partial}{\partial y}(\rho r v) + \frac{1}{r}\frac{\partial}{\partial s}(\rho r w) = 0 \tag{2a}$$

MOMENTUM

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{1}{r}w\frac{\partial u}{\partial s} - \frac{r'(x)}{r}w^2\right) = -\frac{\partial p}{\partial x} + \frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}\right) \tag{2b}$$

$$\frac{\partial p}{\partial y} \sim O(1) \tag{2c}$$

$$\rho\left(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + \frac{w}{r}\frac{\partial w}{\partial s} + \frac{r'(x)}{r}uw\right) = -\frac{1}{r}\frac{\partial p}{\partial s} + \frac{\partial}{\partial y}\left(\mu\frac{\partial w}{\partial y}\right) \tag{2d}$$

ENERGY

$$\rho\left(u\frac{\partial \varepsilon}{\partial x} + v\frac{\partial \varepsilon}{\partial y} + \frac{w}{r}\frac{\partial \varepsilon}{\partial s}\right) = -p\left[\frac{1}{r}\frac{\partial}{\partial x}(ru) + \frac{\partial v}{\partial y} + \frac{1}{r}\frac{\partial w}{\partial s}\right] + \mu\left[\left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial y}\right)^2\right] + \frac{\partial}{\partial y}\left(K\frac{\partial T}{\partial y}\right) \tag{2e}$$

STATE

$$p = \rho R T \tag{2f}$$

The energy equation (2e) can be simplified by combining (2a) and (2f) with (2e) and recalling the definition of the enthalpy $h = E + p/\rho$ and making the assumption that the Prandtl number is constant. Thus the energy equation becomes

$$\rho\left(u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} + \frac{w}{r}\frac{\partial h}{\partial s}\right) = u\frac{\partial p}{\partial x} + \frac{w}{r}\frac{\partial p}{\partial s}$$
$$+ \mu\left[\left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial y}\right)^2\right] + \frac{1}{Pr}\frac{\partial}{\partial y}\left(\mu\frac{\partial h}{\partial y}\right) \tag{3}$$

The appropriate boundary conditions for the above equations are

At $y = 0$: $u=v=w=0$, $h=h_w$ (constant wall temperature)

or $\frac{\partial h}{\partial y} = 0$ (zero heat transfer)

As $y \to \infty$: $u=u_e$, $w=w_e$, $h=h_e$

II. 2 Inviscid Flow Field

In order to examine the boundary layer development on a yawed cone, it is necessary to have some means of describing the inviscid flow field about the body, particularly the components of velocity and the properties of state occurring on the body surface. Sims has prepared an extensive set of tables (Ref. 7 and 8) which adequately describes the inviscid flow field past a circular cone at small angles of attack. It is based on Stone's theory (Ref. 13) which is essentially a perturbation of the flow variables from their values at zero angle of attack. Sims' results actually apply at the outer edge of the vortical layer which is a transition region

in which the form of the entropy changes from a constant value at the cone surface to a cosine variation to first order in angle of attack away from the surface. However, Moore in reference 2 argues that the boundary layer flow is governed by the flow field external to the vortical layer if the boundary layer is much thicker than the vortical layer. Thus in this case the results of Stone's theory can be applied without any appreciable error being introduced. Further verification that the vortical layer can be neglected in practice can be found in reference 9.

On the cone surface, the theory for small angles of attack used in reference 8 yields results which may be written in the following dimensionless (see page 12) manner:

$$u_e^* = 1 + \alpha A \cos\phi \tag{4a}$$

$$w_e^* = \alpha B \sin\phi \tag{4b}$$

$$\rho_e^* = 1 + \alpha P_2 \cos\phi \tag{4c}$$

$$T_e^* = T_{c_1}^* - \alpha D \cos\phi \tag{4d}$$

Where the coefficients A, B, P_2, D are given by the following relations in terms of quantities (evaluated at the cone surface) tabulated in references 7 and 8 and are independent of α, the angle of attack:

$$A = \frac{M_2^*}{M_1^*} \tag{5a}$$

$$B = \frac{-\sqrt{\frac{\gamma+1}{\gamma-1}}\left(\frac{\rho_1}{\rho_1 u_1}\right)_s \frac{S_2}{R} - M_2^*}{\sin\theta_c \, M_1^*} \tag{5b}$$

$$P_2 = -\left[\frac{2\gamma M_1^* M_2^*}{(\gamma+1)-(\gamma-1)M_1^*} + \frac{S_2}{R}\right] \tag{5c}$$

$$D = \frac{2 M_1^* M_2^* (\gamma-1) T_1^*}{(\gamma+1)-(\gamma-1) M_1^{*2}} \tag{5d}$$

The right hand sides of the above expressions are in the notation of reference 8. The subscript "1" refers to quantities evaluated at zero angle of attack while "2" refers to those evaluated at an angle of attack.

Equations (4) give the boundary conditions to be imposed on the viscous flow at the outer edge of the boundary layer.

II. 3 Definition of the Vector Potential

In steady compressible two-dimensional flow the stream function, defined so as to identically satisfy the continuity equation, is introduced in order to reduce the number of dependent variables occurring in the governing equations.

In three-dimensional flows, however, the conventional stream function cannot, in general, be used since it does not allow for the extra velocity component present in such flows.

Seeking to extend the stream function concept to steady, three-dimensional flows, Moore in reference 1 introduced a two-component vector potential whereby the scalar functions Ψ and Φ are defined in terms of the mass flow component by writing

$$\rho r u \equiv \frac{\partial \Psi}{\partial y} \tag{6a}$$

$$\rho r v \equiv -\frac{\partial \Psi}{\partial x} - \frac{1}{r}\frac{\partial \Phi}{\partial s} \tag{6b}$$

$$\rho r w \equiv \frac{\partial \Phi}{\partial y} \tag{6c}$$

With these definitions the continuity equation (2a) is identically satisfied and the number of dependent variables reduced by one. Moore in reference 1 pointed out that this particular choice does reduce to the conventional stream function for two-dimensional flow, and he further proved the existence of this two component analog to the stream function for three-dimensional flows.

Substituting the definitions (6) into (2) and (3), the equations of motion, employing the subscript notation for partial differentiation, become

MOMENTUM

$$\frac{1}{r}\Psi_y\left(\frac{1}{\rho r}\Psi_y\right)_x - \frac{1}{r}\left(\Psi_x + \frac{1}{r}\Phi_s\right)\left(\frac{1}{\rho r}\Psi_y\right)_y + \frac{1}{r^2}\Phi_y\left(\frac{1}{\rho r}\Psi_y\right)_s$$

$$-\frac{r'(x)}{r^2}\frac{1}{\rho r}\Phi_y^2 = -p_x + \left[\mu\left(\frac{1}{\rho r}\Psi_y\right)_y\right]_y \tag{7a}$$

$$\frac{1}{r}\Psi_y\left(\frac{1}{\rho r}\Phi_y\right)_x - \frac{1}{r}\left(\Psi_x + \frac{1}{r}\Phi_s\right)\left(\frac{1}{\rho r}\Phi_y\right)_y + \frac{1}{r^2}\Phi_y\left(\frac{1}{\rho r}\Phi_y\right)_s$$

$$+\frac{r'(x)}{r^2}\frac{1}{\rho r}\Psi_y\Phi_y = -\frac{1}{r}p_s + \left[\mu\left(\frac{1}{\rho r}\Phi_y\right)_y\right]_y \tag{7b}$$

ENERGY

$$\frac{1}{r}\Psi_y h_x - \frac{1}{r}\left(\Psi_x + \frac{1}{r}\Phi_s\right) h_y + \frac{1}{r^2}\Phi_y h_s = \frac{1}{\rho r}\Psi_y p_x + \frac{1}{\rho r^2}\Phi_y p_s$$

$$+ \mu\left\{\left[\left(\frac{1}{\rho r}\Psi_y\right)_y\right]^2 + \left[\left(\frac{1}{\rho r}\Phi_y\right)_y\right]^2\right\} + \frac{1}{\rho r}\left(\mu h_y\right)_y \qquad (7c)$$

STATE

$$p = \rho R T \qquad (7d)$$

Here we note that even though $\frac{\partial p}{\partial y} = 0(1)$ in the boundary layer the actual change in pressure in the boundary layer is of the order of the boundary layer thickness δ. Thus for a thin boundary layer we can assume that the pressure in the boundary layer does not depend on the normal co-ordinate and take the value of the pressure in the boundry layer to be the same as that in the external flow. Hence in equations (7) we have $P = P(x,s)$ to order δ.

The boundary conditions to be applied to equations (7) are

At y = 0:

$$u(x,0,s) = 0 \quad \text{or} \quad \Psi_y(x,0,s) = 0 \qquad (8a)$$

$$w(x,0,s) = 0 \quad \text{or} \quad \Phi_y(x,0,s) = 0 \qquad (8b)$$

$$v(x,0,s) = 0 \quad \text{or} \quad \Psi_x(x,0,s) + \frac{1}{r}\Phi_s(x,0,s) = 0 \qquad (8c)$$

$$h(x,0,s) = h_w(x,s) \qquad (8d)$$

As $y \to \infty$:

$$u(x,\infty,s) = u_e(x,s) \quad \text{or} \quad \Psi_y(x,\infty,s) = \rho_e r u_e(x,s) \qquad (8e)$$

$$w(x,\infty,s) = w_e(x,s) \quad \text{or} \quad \Phi_y(x,\infty,s) = \rho_e r w_e(x,s) \qquad (8f)$$

$$h(x,\infty,s) = h_e(x,s) \qquad (8g)$$

Equation (8c) in its present form is not convenient for applications, but Moore in reference 1 shows that it is possible to separate Ψ and Φ with respect to their boundary conditions, and hence equation (8c) may be replaced by

$$\Psi(x,o,s) = \Phi(x,o,s) = 0 \tag{8h}$$

The effect of this substitution is that it causes the solutions for Ψ and Φ to be unique.

II. 4 Viscosity-Temperature Relation

In this report it will be assumed that the variation of viscosity with temperature within the boundary layer can be adequately represented by the Chapman-Rubesin relation (Ref. 10)

$$\frac{\mu}{\bar{\mu}} = C \frac{T}{\bar{T}} \tag{9}$$

where the barred quantities refer to properties in the inviscid flow field at zero angle of attack, evaluated at the cone surface.

The constant C is chosen so as to give the best agreement with the actual viscosity relation over the desired temperature range. For example, if we used the Sutherland formula for the viscosity-temperature relation

$$\frac{\mu}{\bar{\mu}} = \left(\frac{T}{\bar{T}}\right)^{3/2} \left(\frac{\bar{T}+S'}{T+S'}\right) \tag{10}$$

and we are interested in quantities near the surface of the cone,

then we pick C so that equation (9) intersects equation (10) at T_w. Then it follows that

$$C = \sqrt{\frac{T_w}{\bar{T}}}\left(\frac{\bar{T} + S'}{T_w + S'}\right) \tag{11}$$

where

$$S' = (198\,^\circ R)\frac{2C_p}{\bar{u}^2}$$

II. 5 Non-Dimensionalization

It is advantageous to non-dimensionalize the governing equations so that whole families of solutions to the governing equations can be characterized by a single set of equations.

Since this report deals with small angles of attack, and the subsequent small departures of the flow field from that occurring at zero angle of attack, all physical quantities shall be nondimensionalized with respect to the inviscid flow field at zero angle of attack. Letting a bar (—) denote the property at zero angle of attack, evaluated at the cone surface, the following nondimensional quantities appear:

$$\left.\begin{aligned} u^*;\ v^*;\ w^* &= \frac{u}{\bar{u}}\ ;\ \frac{v}{\bar{u}}\ ;\ \frac{w}{\bar{u}} \\ x^*;\ y^*;\ r^* &= x\left(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}}\right)\ ;\ y\left(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}}\right);\ r\left(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}}\right) \\ s^* &= s \quad ;\quad \rho^* = \frac{\rho}{\bar{\rho}} \\ T^* &= \frac{2C_pT}{\bar{u}^2} \quad ;\quad p^* = \frac{p}{\bar{\rho}\bar{u}^2} \end{aligned}\right| \tag{12}$$

$$\mu^* = \frac{\mu}{C\bar{\mu}} \quad ; \quad h^* = \frac{h}{\bar{u}^2}$$

$$\Psi^* \; ; \; \mathfrak{F}^* = \Psi\left(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}}\right)^2 \frac{1}{\bar{\rho}\bar{u}} \quad ; \quad \mathfrak{F}\left(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}}\right)^2 \frac{1}{\bar{\rho}\bar{u}}$$

Since this problem concerns an infinite cone there is no characteristic length as such for the body. The quantity used, $(\frac{\bar{\rho}\bar{u}}{C\bar{\mu}})$, can be considered as a Reynolds number per unit length. This term is related to the propagation of viscous effects in the flow, and for this reason Lagerstrom (Ref. 11) has referred to it as a "viscous length."

II. 6 Transformations of Governing Equations

II. 6.1 Howarth's Transformation

The system of governing equations given by equations (7), while complete, is complicated and would be difficult to solve. Thus the next step in the development of the problem is to seek possible simplifications of the governing equations.

In an attempt to simplify the laminar, compressible boundary layer equations, Howarth developed a transformation which, for zero pressure gradient in the x-direction and μ proportional to T, correlates compressible and incompressible boundary layers. By suitably stretching the normal coordinate, he was able to reduce the compressible boundary layer equations to an almost incompressible form.

For the problem under consideration the following transformations are employed (in non-dimensionalized form) following Moore (Ref. 1):

$$Y \equiv \left(\frac{\rho^*}{\bar{\rho}^*}\right)^{-\frac{1}{2}} \int_0^{y^*} \rho^* \, dy^* \tag{13a}$$

$$X \equiv x^* \quad , \quad S \equiv s^* \tag{13b}$$

$$\Psi^* \equiv \left(\frac{\rho^*}{\bar{\rho}^*}\right)^{\frac{1}{2}} \tilde{\Psi} \tag{13c}$$

$$\Phi^* \equiv \left(\frac{\rho^*}{\bar{\rho}^*}\right)^{\frac{1}{2}} \tilde{\Phi} \tag{13d}$$

Also, since $p = p(x,\phi)$ only, we have

$$\frac{\partial}{\partial x^*} = \frac{\partial}{\partial X} + \frac{\partial Y}{\partial x^*} \frac{\partial}{\partial Y} \tag{14a}$$

$$\frac{\partial}{\partial s^*} = \frac{\partial}{\partial S} + \frac{\partial Y}{\partial s^*} \frac{\partial}{\partial Y} \tag{14b}$$

$$\frac{\partial}{\partial y^*} = \rho^* \left(\frac{\rho^*}{\bar{\rho}^*}\right)^{-\frac{1}{2}} \frac{\partial}{\partial Y} \tag{14c}$$

Applying equations (9), (12), (13), and (14) to the governing equations (7), we have the following system of equations:

MOMENTUM

$$\tilde{\Psi}_Y \left(\frac{1}{r^*} \tilde{\Psi}_Y\right)_X - \left(\tilde{\Psi}_X + \frac{1}{r^*} \tilde{\Phi}_S\right)\left(\frac{1}{r^*} \tilde{\Psi}_Y\right)_Y + \frac{1}{r^*} \tilde{\Phi}_Y \left(\frac{1}{r^*} \tilde{\Psi}_Y\right)_S - \frac{r^{*\prime}}{r^{*2}} \left(\tilde{\Phi}_Y\right)^2$$

$$= -\frac{r^*}{\rho^*} p_X^* + \frac{1}{2}\left(\frac{\rho_X^*}{\rho^*} \tilde{\Psi} + \frac{1}{r^*} \frac{\rho_S^*}{\rho^*} \tilde{\Phi}\right)\left(\frac{1}{r^*} \tilde{\Psi}_Y\right)_Y + \tilde{\Psi}_{YYY} \tag{15a}$$

$$\tilde{\Psi}_Y \left(\frac{1}{r^*} \tilde{\Phi}_Y\right)_X - \left(\tilde{\Psi}_X + \frac{1}{r^*} \tilde{\Phi}_S\right)\left(\frac{1}{r^*} \tilde{\Phi}_Y\right)_Y + \frac{1}{r^*} \tilde{\Phi}_Y \left(\frac{1}{r^*} \tilde{\Phi}_Y\right) + \frac{r^{*\prime}}{r^{*2}} \tilde{\Phi}_Y \tilde{\Psi}_Y =$$

$$-\frac{1}{\rho^*}\,p^*_s + \frac{1}{2}\left(\frac{p^*_x}{\rho^*}\,\tilde{\Psi} + \frac{1}{r^*}\,\frac{p^*_s}{\rho^*}\,\tilde{\Phi}\right)\left(\frac{1}{r^*}\,\tilde{\Phi}_Y\right)_Y + \tilde{\Phi}_{YYY} \tag{15b}$$

ENERGY

$$\frac{1}{r^*}\left[\tilde{\Psi}_Y\,h^*_x - \left(\tilde{\Psi}_x + \frac{1}{r^*}\,\tilde{\Phi}_s\right)h^*_Y + \frac{1}{r^*}\,\tilde{\Phi}_Y\,h^*_s\right] = \frac{1}{\rho^* r^*}\left(\tilde{\Psi}_Y\,p^*_x + \frac{1}{r^*}\,\tilde{\Phi}_Y\,p^*_s\right)$$

$$+\frac{1}{2r^*}\left(\frac{p^*_x}{\rho^*}\,\tilde{\Psi} + \frac{1}{r^*}\,\frac{p^*_s}{\rho^*}\,\tilde{\Phi}\right)h^*_Y + \frac{1}{r^{*2}}\left[\left(\tilde{\Psi}_{YY}\right)^2 + \left(\tilde{\Phi}_{YY}\right)^2\right] + \frac{1}{Pr}\,h^*_{YY} \tag{15c}$$

STATE

$$\frac{\rho^*}{\rho^*} = \rho^*\,\frac{T^*}{T^*} \tag{15d}$$

The velocities under this transformation are given by

$$r^*u^* = \frac{1}{\rho^*}\,\Psi^*_{y^*} = \tilde{\Psi}_Y \tag{16a}$$

$$r^*w^* = \frac{1}{\rho^*}\,\Phi^*_{y^*} = \tilde{\Phi}_Y \tag{16b}$$

II. 6. 2 Mangler's Transformation

The purpose of Mangler's transformation is to reduce the equations for an axially symmetric flow to those of a plane flow. The object is to eliminate the explicit dependence of the "r" term in the equations (15). With this in mind, it is convenient to define the transformation in the following manner:

$$\xi \equiv k^2 \int_0^X r^{*2}\, dX = \frac{k^2 r^{*3}}{3\Theta} \tag{17a}$$

$$\eta \equiv k r^* Y \tag{17b}$$

$$\phi \equiv S \tag{17c}$$

$$F \equiv k\tilde{\Psi} \tag{17d}$$

$$G \equiv k\tilde{\Phi} \tag{17e}$$

Where k is an arbitrary constant.

The functions p^*, ρ^*, and T^* are not transformed.

Thus,

$$\frac{\partial}{\partial X} = k^2 r^{*2} \frac{\partial}{\partial \xi} + \frac{\partial \eta}{\partial X} \frac{\partial}{\partial \eta} \tag{17f}$$

$$\frac{\partial}{\partial Y} = k r^* \frac{\partial}{\partial \eta} \tag{17g}$$

$$\frac{\partial}{\partial S} = \frac{\partial}{\partial \phi} \tag{17h}$$

The velocity components now become

$$u^* = \frac{1}{r^*} \tilde{\Psi}_Y = F_\eta \tag{18a}$$

$$w^* = \frac{1}{r^*} \tilde{\Phi}_Y = G_\eta \tag{18b}$$

Applying these relations to equations (15) we arrive at the following set of equations:

MOMENTUM

$$F_\eta F_{\eta\xi} - \left(F_\xi + \frac{1}{3\Theta_\xi} G_\phi \right) F_{\eta\eta} + \frac{1}{3\Theta_\xi} G_\eta F_{\eta\phi} - \frac{1}{3\xi} G_\eta^2 = -\frac{1}{\rho^*} p_\xi^*$$

$$+ \frac{1}{2} \left(\frac{p_\xi^*}{p^*} F + \frac{1}{3\Theta_\xi} \frac{p_\phi^*}{p^*} G \right) F_{\eta\eta} + F_{\eta\eta\eta} \tag{19a}$$

$$F_\eta G_{\eta\xi} - \left(F_\xi + \frac{1}{3\theta\xi} G_\phi\right) G_{\eta\eta} + \frac{1}{3\theta\xi} G_\eta G_{\eta\phi} + \frac{1}{3\xi} G_\eta F_\eta =$$

$$-\frac{1}{3\theta\xi}\,\frac{1}{\rho^*}\,p^*_\phi + \frac{1}{2}\left(\frac{p^*_\xi}{\rho^*} F + \frac{1}{3\theta\xi}\,\frac{p^*_\phi}{\rho^*} G\right) G_{\eta\eta} + G_{\eta\eta\eta} \qquad (19b)$$

ENERGY

$$F_\eta h^*_\xi - \left(F_\xi + \frac{1}{3\theta\xi} G_\phi\right) h^*_\eta + \frac{1}{3\theta\xi} G_\eta h^*_\phi = \frac{1}{2}\left(\frac{p^*_\xi}{\rho^*} F + \frac{1}{3\theta\xi}\,\frac{p^*_\phi}{\rho^*} G\right) h^*_\eta$$

$$+\frac{1}{\rho^*}\left(F_\eta p^*_\xi + \frac{1}{3\theta\xi} G_\eta p^*_\phi\right) + F_{\eta\eta}^2 + G_{\eta\eta}^2 + \frac{1}{Pr} h^*_{\eta\eta} \qquad (19c)$$

STATE

$$\frac{p^*}{\rho^*} = \rho^* \frac{T^*}{T^*} \qquad (19d)$$

The corresponding boundary conditions become:

At $\eta = 0$:

$$F_\eta(\xi, 0, \phi) = F(\xi, 0, \phi) = 0 \qquad (20a)$$

$$G_\eta(\xi, 0, \phi) = G(\xi, 0, \phi) = 0 \qquad (20b)$$

$$h^*(\xi, 0, \phi) = h^*_w \qquad (20c)$$

As $\eta \to \infty$:

$$F_\eta(\xi, \infty, \phi) = u^*_e(\xi, \phi) \qquad (20d)$$

$$G_\eta(\xi, \infty, \phi) = w^*_e(\xi, \phi) \qquad (20e)$$

$$h^*(\xi, \infty, \phi) = h^*_e(\xi, \phi) \qquad (20f)$$

II. 6.3 Supersonic Conical Flow and Similarity

It is known that in the inviscid, conical flow existing outside the boundary layer on the cone in supersonic flow, the fluid properties (i.e., velocity, pressure, density, temperature, etc.) are constant along rays from the apex of the cone. In particular, $\bar{p}^*_{\xi} = 0$. This implies that if we consider the boundary layer equations along a ray of the cone, there will be no pressure gradient in this direction and hence a Blasius type similarity transformation might be possible. Thus in analogy with the Blasius analysis define

$$\lambda \equiv \eta \xi^{-\frac{1}{2}} = \sqrt{3}\left[\left(\frac{\rho^*}{\bar{\rho}^*}\right)^{-\frac{1}{2}} \int_0^{y^*} \rho^* dy^*\right] (x^*)^{-\frac{1}{2}} \tag{21a}$$

$$F \equiv \xi^{\frac{1}{2}} f(\lambda, \phi) \tag{21b}$$

$$G \equiv \xi^{\frac{1}{2}} g(\lambda, \phi) \tag{21c}$$

$$h^* \equiv h^*(\lambda, \phi) \tag{21d}$$

$$\rho^* \equiv \rho^*(\lambda, \phi) \tag{21e}$$

$$T^* \equiv T^*(\lambda, \phi) \tag{21f}$$

With these definitions the velocity components become

$$u^* = F_\eta = f_\lambda \tag{22a}$$

$$w^* = G_\eta = g_\lambda \tag{22b}$$

and the boundary layer equations (19) become

MOMENTUM

$$\left(f + \frac{1}{3\theta}\frac{p^{*\prime}(\phi)}{p^*} g + \frac{2}{3\theta} g_\phi\right) f_{\lambda\lambda} - \frac{2}{3\theta} g_\lambda f_{\lambda\phi} + \frac{2}{3} g_\lambda^2 + 2 f_{\lambda\lambda\lambda} = 0 \qquad (23a)$$

$$\left(f + \frac{1}{3\theta}\frac{p^{*\prime}(\phi)}{p^*} g + \frac{2}{3\theta} g_\phi\right) g_{\lambda\lambda} - \frac{2}{3\theta} g_\lambda g_{\lambda\phi} - \frac{2}{3} g_\lambda f_\lambda + \frac{p^{*\prime}(\phi)}{p^*} + 2 g_{\lambda\lambda\lambda} = 0 \qquad (23b)$$

ENERGY

$$\left(f + \frac{1}{3\theta}\frac{p^{*\prime}(\phi)}{p^*} g + \frac{2}{3\theta} g_\phi\right) h^*_\lambda - \frac{2}{3\theta} g_\lambda h^*_\phi + \frac{2}{3\theta} g_\lambda \frac{p^{*\prime}(\phi)}{p^*}$$

$$+ 2\left(f_{\lambda\lambda}^2 + g_{\lambda\lambda}^2\right) + \frac{2}{Pr} h^*_{\lambda\lambda} = 0 \qquad (23c)$$

STATE

$$\frac{p^*}{\bar{p}^*} = \rho^* \frac{T^*}{\bar{T}^*} \qquad (23d)$$

Since $h^* = \frac{1}{2}T^*$ equation (23c) may be rewritten as

$$\left(f + \frac{1}{3\theta}\frac{p^{*\prime}(\phi)}{p^*} g + \frac{2}{3\theta} g_\phi\right) T^*_\lambda - \frac{2}{3\theta} g_\lambda T^*_\phi + \frac{4}{3\theta} g_\lambda \frac{p^{*\prime}(\phi)}{p^*}$$

$$+ 4\left(f_{\lambda\lambda}^2 + g_{\lambda\lambda}^2\right) + \frac{2}{Pr} T^*_{\lambda\lambda} = 0 \qquad (23c')$$

The boundary conditions (20) are now

At $\lambda = 0$:

$$f_\lambda(0,\phi) = f(0,\phi) = 0 \tag{24a}$$

$$g_\lambda(0,\phi) = g(0,\phi) = 0 \tag{24b}$$

$$T^*(0,\phi) = T_w^* \tag{24c}$$

As $\lambda \to \infty$:

$$f_\lambda(\infty,\phi) = u_e^*(\phi) \tag{24d}$$

$$g_\lambda(\infty,\phi) = w_e^*(\phi) \tag{24e}$$

$$T^*(\infty,\phi) = T_e^*(\phi) \tag{24f}$$

For zero heat transfer replace (24c) by

$$T_\lambda^*(0,\phi) = 0 \tag{24g}$$

We have a system of three equations for the three unknowns f, g, T^* in terms of two independent variables λ, ϕ.

For the case of small angle of attack these equations are now reduced to a form consistent with the external flow field about a yawed cone as given by equations (4).

III. SOLUTION OF THE GOVERNING EQUATIONS

III. 1 Formulation of the Perturbation Equations

In the remainder of this report, the laminar boundary layer on a yawed cone will be treated as a perturbation of the basic flow at zero angle of attack, i.e., we will assume that

$$\epsilon \equiv \frac{\alpha}{\theta} << 1 \tag{25}$$

Letting the subscript "1" denote the basic flow field, and "2" the first order correction terms we can express $f(\lambda, \phi)$, $g(\lambda, \phi)$, and $T^*(\lambda, \phi)$ as follows:

$$f(\lambda,\phi) = f_1(\lambda) + \epsilon A_2 \cos\phi\, f_2(\lambda) + \cdots \tag{26a}$$

$$g(\lambda,\phi) = \epsilon B_2 \sin\phi\, g_2(\lambda) + \cdots \tag{26b}$$

$$T^*(\lambda,\phi) = T_1^*(\lambda) - \epsilon D_2 \cos\phi\, T_2^*(\lambda) + \cdots \tag{26c}$$

It is also possible to express the pressure and density terms appearing in equations (23) in perturbation form.

From the results presented in Sims Tables (Refs. 7, 8) for the external flow field we can write the pressure distribution on the cone surface to first order in ϵ as

$$p_e^* = \overline{p}^* \left(1 + \epsilon(\theta P_2)\cos\phi\right) \tag{27}$$

where P_2 is defined by equation (5c).

Since we've assumed that the pressure does not vary through the boundary layer (i.e., $p^* = p_e^*$) using equation (27) we are able to find

$$\frac{p^{*\prime}}{p^*} = -\epsilon(\theta P_2)\sin\phi \tag{28}$$

In a similar manner it is possible to express $\frac{p^{*'}}{\rho^{*}}$ in perturbation form. From the equation of state

$$\frac{1}{\rho^{*}} = \left(\frac{\gamma-1}{2\gamma}\right)\frac{T^{*}}{p_e^{*}}$$

$$= \left(\frac{\gamma-1}{2\gamma}\right)\frac{T^{*}}{\bar{p}^{*}}\left(1-\epsilon(\Theta P_2)\cos\phi\right) \qquad (29)$$

Multiplying $p^{*'}$ from equation (28) by equation (29) we have to first order in ϵ

$$\frac{p_{\phi}^{*'}}{\rho^{*}} = -\frac{\gamma-1}{2\gamma}\epsilon(\Theta P_2)\sin\phi\, T^{*} \qquad (30)$$

Substituting equations (26), (28) and (30) into (23) and equating the terms of unit order (ϵ^{0}) to zero give

$$f_1 f_1''' + 2f_1''' = 0 \qquad (31a)$$

$$f_1 T_1^{*'} + 4f_1''^{2} + \frac{2}{Pr} T_1^{*''} = 0 \qquad (31b)$$

Next the sums of terms of order ϵ are equated to zero, giving

$$3f_1 g_2'' - 2g_2' f_1' + \left(\frac{\gamma-1}{\gamma}\frac{P_2}{B_2}\right) T_1^{*} + 6g_2''' = 0 \qquad (32)$$

$$3f_1 f_2'' + 3f_1'' f_2 + \left(\frac{2B_2}{\Theta A_2}\right) f_1'' g_2 + 6f_2''' = 0 \qquad (33b)$$

$$3f_2 T_1^{*'} + \left(\frac{2B_2}{\Theta A_2}\right) g_2 T_1^{*'} - 3\left(\frac{D_2}{A_2}\right) f_1 T_2^{*'} + 24 f_1'' f_2'' - \frac{6}{Pr}\left(\frac{D_2}{A_2}\right) T_2^{*''} = 0 \qquad (33c)$$

Substituting equations (4) and (26) into the boundary conditions (24) and equating terms of like order in ϵ defines the heretofore unspecified constants A_2, B_2, D_2 and provides the necessary boundary conditions to which equations (31), (32) and (33)

are subject:

$$A_2 = \Theta A \quad ; \quad B_2 = \Theta B \quad ; \quad D_2 = \Theta D \tag{34}$$

where A, B, D are defined by equation (5).

$$f_1'(0) = f_1(0) = 0 \quad , \quad f_1'(\infty) = 1 \tag{35a}$$

$$f_2'(0) = f_2(0) = 0 \quad , \quad f_2'(\infty) = 1 \tag{35b}$$

$$g_2'(0) = g_{g_2}(0) = 0 \quad , \quad g_2'(\infty) = 1 \tag{36}$$

$$\left.\begin{aligned} & T_1^*(0) = T_w^* \quad , \quad T_1^*(\infty) = \bar{T}^* \\ & \text{or} \quad T_1^{*\prime}(0) = 0 \ \text{(insulated wall)} \end{aligned}\right\} \tag{37a}$$

$$\left.\begin{aligned} & T_2^*(0) = 0 \quad , \quad T_2^*(\infty) = 1 \\ & \text{or} \quad T_2^{*\prime}(0) = 0 \ \text{(insulated wall)} \end{aligned}\right\} \tag{37b}$$

Due to the boundary conditions (35a), (36), and (37a) the relation

$$\frac{\gamma - 1}{\gamma} \frac{P_2}{B_2} \bar{T}^* = 2 \tag{38}$$

must hold in order that equation (32) be satisfied as $\lambda \to \infty$.

Hence equation (32) can be written as

$$3 f_1 g_2'' - 2 g_2' f_1' + \frac{2}{\bar{T}^*} T_1^* + 6 g_2''' = 0 \tag{33a}$$

Equations (31) govern the velocity and thermal boundary layers on a cone at zero angle of attack in a supersonic stream. Formally they are identical to those for plane flow over a flat plate, the difference between the flat plate and cone cases being a factor of

$\sqrt{3}$ in the definition of the independent variable. We have two ordinary differential equations for the unknowns $f_1(\lambda)$ and $T_1^*(\lambda)$. Equations (33) represent the first order corrections in the flow field due to a small angle of attack ($\varepsilon<<1$). There are three ordinary differential equations for the three unknowns $g_2(\lambda)$, $f_2(\lambda)$ and $T_2^*(\lambda)$.

The only dependent variable appearing in equation (31a) is f_1 so that the solution of this equation is independent of all the following equations ((31b), (33)). Furthermore, each succeeding equation involves only one new dependent variable, so that each equation can be solved once the preceding equations have been solved. With the aid of a computer it is possible to find numerical solutions in a straightforward manner. However, before proceeding to solve equations ((31b), (33)) numerically it is advantageous to eliminate the parameters related to a particular geometry and flow field from the equations and boundary conditions. The functions $T_1^*(\lambda)$, $g_2(\lambda)$, $f_2(\lambda)$ and $T_2^*(\lambda)$ can be expressed as linear combinations of functions which do not depend on physical parameters in question. This yields a set of two-point boundary value problems which can be solved once and for all, independent of the physical parameters in question. By the appropriate linear combination of these "universal functions" it is possible to calculate the boundary layer characteristics for any particular problem in mind.

III. 2 Development of Universal Functions

For computational purposes it is advantageous to consider the insulated cone problem separately from the non-insulated one. Thus, in what follows we shall consider independently the two problems: the laminar boundary layer with heat transfer on a yawed cone, and the laminar boundary layer on a yawed, insulated cone. The only parameter appearing in the solution of the differential equations is the Prandtl number which is constant, but otherwise arbitrary. (Note: For a cone, the terms angle of attack and yawed are synonymous)

III. 2.1 Differential Equations for the Flow with Heat Transfer

To eliminate the parameters appearing in equations (31) and (33), and in the boundary condition(37a), the functions $T_1^*(\lambda)$, $g_2(\lambda)$, $f_2(\lambda)$, and $T_2^*(\lambda)$ are expressed as a linear combination of functions not depending on these parameters. Thus, define

$$T_1^*(\lambda) = T_w^* - (T_w^* - \bar{T}^*)\, T_{11}(\lambda) - T_{12}(\lambda) \tag{39}$$

$$g_2(\lambda) = f_1(\lambda) + \frac{2}{\bar{T}^*}\left(g_{21}(\lambda) + T_w^* g_{22}(\lambda)\right) + g_{23}(\lambda) \tag{40}$$

$$f_2(\lambda) = f_{21}(\lambda) + \frac{2B}{\Theta A}\left[f_{22}(\lambda) + \frac{2}{\bar{T}^*}\left(f_{23}(\lambda) + T_w^* f_{24}(\lambda)\right)\right] \tag{41}$$

$$\begin{aligned} T_2^*(\lambda) = {} & T_{11}(\lambda) + \frac{A}{D}\Big\{ (T_w^* - \bar{T}^*)\Big[T_{21}(\lambda) + \frac{2B}{\Theta A}\Big(T_{22}(\lambda) \\ & + \frac{2}{\bar{T}^*} T_{23}(\lambda) + \frac{2}{\bar{T}^*} T_w^* T_{24}(\lambda)\Big)\Big] + T_{25}(\lambda) \\ & + \frac{2B}{\Theta A}\Big(T_{26}(\lambda) + \frac{2}{\bar{T}^*} T_{27}(\lambda) + \frac{2}{\bar{T}^*} T_w^* T_{28}(\lambda)\Big)\Big\} \end{aligned} \tag{42}$$

The coefficients in these equations can be determined for any particular problem from equations (5) and Sims' Tables (Ref. 7 and 8). Upon substituting equations (39) through (42) into (31) and (33), the following differential equations and boundary conditions for supersonic flow over a yawed cone with heat transfer are obtained:

$$f_1 f_1'' + 2 f_1''' = 0 \tag{43a}$$

$$f_1'(0) = f_1(0) = 0 \quad , \quad f_1'(\infty) = 1 \tag{43b}$$

$$f_1 T_{11}' + \frac{2}{Pr} T_{11}'' = 0 \tag{44a}$$

$$T_{11}(0) = 0 \quad , \quad T_{11}(\infty) = 1 \tag{44b}$$

$$f_1 T_{12}' + \frac{2}{Pr} T_{12}'' = 4 (f_1'')^2 \tag{45a}$$

$$T_{12}(0) = T_{12}(\infty) = 0 \tag{45b}$$

$$3 f_1 g_{21}'' - 2 f_1' g_{21}' + 6 g_{21}''' = T_{12} \tag{46a}$$

$$g_{21}'(0) = g_{21}(0) = g_{21}'(\infty) = 0 \tag{46b}$$

$$3 f_1 g_{22}'' - 2 f_1' g_{22}' + 6 g_{22}''' = T_{11} - 1 \tag{47a}$$

$$g_{22}'(0) = g_{22}(0) = g_{22}'(\infty) = 0 \tag{47b}$$

$$3 f_1 g_{23}'' - 2 f_1' g_{23}' + 6 g_{23}''' = 2 \left((f_1')^2 - T_{11} \right) \tag{48a}$$

$$g_{23}'(0) = g_{23}(0) = g_{23}'(\infty) = 0 \tag{48b}$$

$$f_1'' f_{21} + f_1 f_{21}'' + 2 f_{21}''' = 0 \tag{49a}$$

$$f_{21}'(0) = f_{21}(0) = 0 \quad , \quad f_{21}'(\infty) = 1 \tag{49b}$$

$$f_1'' f_{22} + f_1 f_{22}'' + 2 f_{22}''' = -\frac{1}{3} f_1'' (f_1 + g_{23}) \tag{50a}$$

$$f_{22}'(0) = f_{22}(0) = f_{22}'(\infty) = 0 \tag{50b}$$

$$f_1'' f_{23} + f_1 f_{23}'' + 2 f_{23}''' = -\frac{1}{3} f_1'' g_{21} \tag{51a}$$

$$f_{23}'(0) = f_{23}(0) = f_{23}'(\infty) = 0 \tag{51b}$$

$$f_1'' f_{24} + f_1 f_{24}'' + 2 f_{24}''' = -\frac{1}{3} f_1'' g_{22} \tag{52a}$$

$$f_{24}'(0) = f_{24}(0) = f_{24}'(\infty) = 0 \tag{52b}$$

$$f_1 T_{21}' + \frac{2}{Pr} T_{21}'' = -T_{11}' f_{21} \tag{53a}$$

$$T_{21}(0) = T_{21}(\infty) = 0 \tag{53b}$$

$$f_1 T_{22}' + \frac{2}{Pr} T_{22}'' = -\frac{1}{3} T_{11}' (3 f_{22} + f_1 + g_{23}) \tag{54a}$$

$$T_{22}(0) = T_{22}(\infty) = 0 \tag{54b}$$

$$f_1 T_{23}' + \frac{2}{Pr} T_{23}'' = -\frac{1}{3} T_{11}' (3 f_{23} + g_{21}) \tag{55a}$$

$$T_{23}(0) = T_{23}(\infty) = 0 \tag{55b}$$

$$f_1 T_{24}' + \frac{2}{Pr} T_{24}'' = -\frac{1}{3} T_{11}' (3 f_{24} + g_{22}) \tag{56a}$$

$$T_{24}(0) = T_{24}(\infty) = 0 \tag{56b}$$

$$f_1 T_{25}' + \frac{2}{Pr} T_{25}'' = 8 f_1'' f_{21}'' - T_{12}' f_{21} \tag{57a}$$

$$T_{25}(0) = T_{25}(\infty) = 0 \tag{57b}$$

$$f_1 T_{26}' + \frac{2}{Pr} T_{26}'' = -\frac{1}{3} \left[T_{12}' (3 f_{22} + f_1 + g_{23}) - 24 f_1'' f_{22}'' \right] \tag{58a}$$

$$T_{26}(0) = T_{26}(\infty) = 0 \tag{58b}$$

$$f_1 T_{27}' + \frac{2}{Pr} T_{27}'' = -\frac{1}{3}\left(T_{12}' (3 f_{23} + g_{21}) - 24 f_1'' f_{23}'' \right) \tag{59a}$$

$$T_{27}(0) = T_{27}(\infty) = 0 \tag{59b}$$

$$f_1 T_{28}' + \frac{2}{Pr} T_{28}'' = -\frac{1}{3}\left(T_{12}' (3 f_{24} + g_{22}) - 24 f_1'' f_{24}'' \right)$$

$$T_{28}(0) = T_{28}(\infty) = 0$$

We have a set of 18 uncoupled, linear (with the exception of equation (43)), ordinary differential equations which depend only on the Prandtl number. With a specified Prandtl number the equations may be solved once and for all, independent of the physical parameters of the problem. The numerical solutions to these equations will be briefly discussed in Appendix A. The results, for Prandtl number of 0.72 and 1.0, are tabulated in Tables I and II.

III. 2.2 Differential Equations for Flow Without Heat Transfer

The case of zero heat transfer is treated in an analogous manner to the heat transfer case above. We define

$$T_1^*(\lambda) = \bar{T}^* + \tilde{T}_{11}(\lambda) \tag{61}$$

$$g_2(\lambda) = \tilde{g}_{21}(\lambda) + \frac{2}{\bar{T}^*} \tilde{g}_{22}(\lambda) \tag{62}$$

$$f_2(\lambda) = \tilde{f}_{21}(\lambda) - \frac{2B}{\Theta A}\left(\frac{2}{\bar{T}^*} \tilde{f}_{22}(\lambda) + \tilde{f}_{23}(\lambda) \right) \tag{63}$$

$$T_2^*(\lambda) = 1 + \frac{A}{D}\left(\tilde{T}_{21}(\lambda) + \frac{2B}{\Theta A}\left\{\frac{2}{T^*}\,\tilde{T}_{22}(\lambda) + \tilde{T}_{23}(\lambda)\right\}\right) \tag{64}$$

Substituting these relations into equations (31) and (33) yield the governing equations and boundary conditions for supersonic flow over an insulated cone at small angle of attack:

$$\tilde{f}_1\tilde{f}_1'' + 2\tilde{f}_1''' = 0 \tag{65a}$$

$$\tilde{f}_1'(0) = \tilde{f}_1(0) = 0 \quad , \quad \tilde{f}_1'(\infty) = 1 \tag{65b}$$

$$\tilde{f}_1\tilde{T}_{11}' + \frac{2}{Pr}\tilde{T}_{11}'' = -4\left(\tilde{f}_1''\right)^2 \tag{66a}$$

$$\tilde{T}_{11}(0) = \tilde{T}_{11}(\infty) = 0 \tag{66b}$$

$$3\tilde{f}_1\tilde{g}_{21}'' - 2\tilde{f}_1'\tilde{g}_{21}' + 6\tilde{g}_{21}''' = -2 \tag{67a}$$

$$\tilde{g}_{21}'(0) = \tilde{g}_{21}(0) = 0 \quad , \quad \tilde{g}_{21}'(\infty) = 1 \tag{67b}$$

$$3\tilde{f}_1\tilde{g}_{22}'' - 2\tilde{f}_1'\tilde{g}_{22}' + 6\tilde{g}_{21}''' = -\tilde{T}_{11} \tag{68a}$$

$$\tilde{g}_{22}'(0) = \tilde{g}_{22}(0) = \tilde{g}_{22}(\infty) = 0 \tag{68b}$$

$$\tilde{f}_1''\tilde{f}_{21} + \tilde{f}_1\tilde{f}_{21}'' + 2\tilde{f}_{21}''' = 0 \tag{69a}$$

$$\tilde{f}_{21}'(0) = \tilde{f}_{21}(0) = 0 \quad , \quad \tilde{f}_{21}'(\infty) = 1 \tag{69b}$$

$$\tilde{f}_1''\tilde{f}_{22} + \tilde{f}_1\tilde{f}_{22}'' + 2\tilde{f}_{22}''' = \frac{1}{3}\tilde{f}_1''\tilde{g}_{22} \tag{70a}$$

$$\tilde{f}_{22}'(0) = \tilde{f}_{22}(0) = \tilde{f}_{22}'(\infty) = 0 \tag{70b}$$

$$\tilde{f}_1''\tilde{f}_{23} + \tilde{f}_1\tilde{f}_{23}'' + 2\tilde{f}_{23}''' = \frac{1}{3}\tilde{f}_1''\tilde{g}_{21} \tag{71a}$$

$$\tilde{f}_{23}'(0) = \tilde{f}_{23}(0) = \tilde{f}_{23}'(\infty) = 0 \tag{71b}$$

$$\tilde{f}_1\tilde{T}_{21}' + \frac{2}{Pr}\tilde{T}_{21}'' = \tilde{T}_{11}'\tilde{f}_{21} + 8\tilde{f}_1''\tilde{f}_{21}' \tag{72a}$$

$$\tilde{T}_{21}'(0) = \tilde{T}_{21}(\infty) = 0 \tag{72b}$$

$$\tilde{f}_1\tilde{T}_{22}' + \frac{2}{Pr}\tilde{T}_{22}'' = \frac{1}{3}\left(\tilde{T}_{11}''(\tilde{g}_{22} - 3\tilde{f}_{22}) - 24\tilde{f}_1''\tilde{f}_{22}''\right) \tag{73a}$$

$$\tilde{T}_{22}'(0) = \tilde{T}_{22}(\infty) = 0 \tag{73b}$$

$$\tilde{f}_1\tilde{T}_{23}' + \frac{2}{Pr}\tilde{T}_{23}'' = \frac{1}{3}\left(\tilde{T}_{11}'(\tilde{g}_{21} - 3\tilde{f}_{23}) - 24\tilde{f}_1''\tilde{f}_{23}''\right) \tag{74a}$$

$$\tilde{T}_{23}'(0) = \tilde{T}_{23}(\infty) = 0 \tag{74b}$$

For this case we have ten uncoupled, ordinary differential equations, again depending only on the Prandtl number. The numerical solutions for these equations are obtained in the same manner as discussed in Appendix A. The results for Prandtl numbers 0.72, and 1.00 are presented in Tables III and IV.

IV BOUNDARY LAYER CHARACTERISTICS

In this section the important boundary layer characteristics arising from a supersonic flow over a yawed cone will be summarized. Before continuing it should be noted that the present analysis is valid only in the limit of vanishing angle of attack. That is, all terms multiplied by ϵ represent rates of change with angle of attack, evaluated at zero angle of attack. Whether or not absolute change for a small finite angle of attack can be obtained from this theory depends on the relative size of the effect computed, rather than on the size of ϵ, and depends further on the unknown second and higher derivatives of the quantity with respect to ϵ.

For ease in application of the analysis, the results for the flow with and without heat transfer will be presented separately.

IV. 1 Flow without Heat Transfer

Velocity and Temperature Profiles - The circumferential and meridional velocity components are given by w^* and u^* respectively.

From equations (21a), (26), (62) and (63) we find

$$w^*(\lambda,\phi) = \epsilon B_2 \sin\phi \left[\tilde{g}'_{21}(\lambda) + \frac{2}{\bar{T}^*}\tilde{g}'_{22}(\lambda)\right] \tag{75}$$

$$u^*(\lambda,\phi) = \tilde{f}'_1(\lambda) + \epsilon A_2 \cos\phi \left[\tilde{f}'_{21}(\lambda) - \frac{2B}{\theta A}\left(\tilde{f}'_{22}(\lambda) + \frac{2}{\bar{T}^*}\tilde{f}'_{23}(\lambda)\right)\right] \tag{76}$$

These equations may be divided by w_e^* and u_e^* given by equations (4) to give, for $\epsilon \ll 1$,

$$\frac{w^*}{w_e^*} = \tilde{g}'_{21}(\lambda) + \frac{2}{\bar{T}^*}\tilde{g}'_{22}(\lambda) \tag{77}$$

$$\frac{u^*}{u_e^*} = \tilde{f}_1'(\lambda) + \epsilon A_2 \cos\phi \left\{ \tilde{f}_{21}'(\lambda) + \frac{2B_2}{\theta A_2}\left(\frac{2}{\bar{T}^*} \tilde{f}_{22}'(\lambda) + \tilde{f}_{23}'(\lambda) \right) - \tilde{f}_1'(\lambda) \right\} \quad (78)$$

In a similar manner using equations (4c), (26c), (61), and (64) we find the following expression for the static temperature ratio

$$\frac{T^*}{T_e^*} = 1 + \frac{\tilde{T}_{11}(\lambda)}{\bar{T}^*} - \epsilon D_2 \cos\phi \left\{ \frac{A_2}{D_2} \left(\tilde{T}_{21}(\lambda) + \frac{2B_2}{\theta A_2} \left[\frac{2}{\bar{T}^*} \tilde{T}_{22}(\lambda) + \tilde{T}_{23}(\lambda) \right] \right) \frac{1}{\bar{T}^*} - \frac{\tilde{T}_{11}(\lambda)}{\bar{T}^{*2}} \right\} \quad (79)$$

In defining heat transfer coefficients the adiabatic wall temperature is a useful reference temperature. Hence, for completeness, the dimensionless adiabatic wall temperature will be defined here as follows:

$$T_{AW}^* = \bar{T}^* + \tilde{T}_{11}(0) - \epsilon D_2 \cos\phi \left\{ 1 + \frac{A_2}{D_2} \left(\tilde{T}_{21}(0) + \frac{2B_2}{\theta A_2} \left[\frac{2}{\bar{T}^*} \tilde{T}_{22}(0) + \tilde{T}_{23}(0) \right] \right) \right\} \quad (80)$$

Skin Friction - In terms of coefficients the meridional and circumferential components of the viscous shear stress at the wall may be written as:

$$C_{f_x} = \frac{2}{\bar{\rho}\bar{u}^2} \left(\mu \frac{\partial u}{\partial y} \right)_w$$

$$C_{f_\phi} = \frac{2}{\bar{\rho}\bar{u}^2} \left(\mu \frac{\partial w}{\partial y} \right)_w$$

The quantities in the above expressions are expressed in dimensional form. In terms of the results presented in this report we can rewrite the expressions as

$$C_{f_\phi} = 2\sqrt{\frac{3G}{Re_x}} \epsilon B_2 \sin\phi \left\{ \tilde{q}_{21}''(0) + \frac{2}{\bar{T}^*} \tilde{q}_{22}''(0) \right\} \quad (81)$$

$$C_{f_x} = 2\sqrt{\frac{3C}{Re_x}}\left\{\tilde{f}_1''(0) + \epsilon A_2 \cos\phi\left[\frac{\Theta P_2}{2A_2}\tilde{f}_1''(0) + \tilde{f}_{21}''(0) - \frac{2B_2}{\Theta A_2}\left(\frac{2}{\bar{T}^*}\tilde{f}_{22}''(0) + \tilde{f}_{23}''(0)\right)\right]\right\} \tag{82}$$

where $Re_x = \dfrac{\bar{\rho}\,\bar{u}\,x}{\bar{u}}$

is a Reynolds number based on the distance from the cone apex and on the fluid properties evaluated in the inviscid flow at the cone surface for a cone at zero angle of attack.

IV. 2 Flow with Heat Transfer

Velocity and Temperature Profiles - The dimensionless velocity ratios in terms of results presented in the report are, using equations (4), (26a, b), (40), and (41), given by

$$\frac{w^*}{w_e^*} = f_1'(\lambda) + g_{23}'(\lambda) + \frac{2}{\bar{T}^*}g_{21}'(\lambda) + \frac{2}{\bar{T}^*}T_w^* g_{22}'(\lambda) \tag{83}$$

$$\frac{u^*}{u_e^*} = f_1'(\lambda) + \epsilon A_2 \cos\phi\left[f_{21}'(\lambda) + \frac{2B_2}{\Theta A_2}\left(f_{22}'(\lambda) + \frac{2}{\bar{T}^*}f_{23}'(\lambda) + \frac{2}{\bar{T}^*}T_w^* f_{24}'(\lambda)\right) - f_1'(\lambda)\right] \tag{84}$$

The temperature ratio is found by combining equations (4c), (26c), (39), and (42):

$$\frac{T^*}{T_e^*} = \frac{1}{\bar{T}^*}\left[T_w^* - (T_w^* - \bar{T}^*)T_{11}(\lambda) - T_{12}(\lambda)\right] - \epsilon\frac{D_2}{\bar{T}^{*2}}\cos\phi\left[T_{11}(\lambda) + \frac{A_2}{D_2}\left[(T_w^* - \bar{T}^*)\left(T_{21}(\lambda) + \frac{2B_2}{\Theta A_2}\left\{T_{22}(\lambda) + \frac{2}{\bar{T}^*}T_{23}(\lambda) + \frac{2}{\bar{T}^*}T_w^* T_{24}(\lambda)\right\}\right)\right.\right.$$

$$+ T_{25}(\lambda) + \frac{2B_2}{\Theta A_2}\left(T_{26}(\lambda) + \frac{2}{\bar{T}^*} T_{27}(\lambda) + \frac{2}{\bar{T}^*} T_W^* T_{28}(\lambda) \right) + \left(T_W^* - \left(T_W^* - \bar{T}^* \right) T_{11}(\lambda) - T_{12}(\lambda) \right) \Bigg\} \Bigg] \tag{85}$$

Skin Friction - Applying the same definitions for the skin friction coefficients used in Section IV. 1 above, the following relations, in terms of the tabulated results, hold:

$$C_{f_\phi} = 2\sqrt{\frac{3G}{Re_x}}\, \epsilon B_2 \sin\phi \left\{ f_1''(0) + g_{23}''(0) + \frac{2}{\bar{T}^*}\left(g_{21}''(0) + T_W^* g_{22}''(0) \right) \right\} \tag{86}$$

$$C_{f_x} = 2\sqrt{\frac{3G}{Re_x}} \left\{ f_1''(0) + \epsilon A_2 \cos\phi \left[\frac{\Theta P_2}{2 A_2} f_1''(0) + f_{21}''(0) + \frac{2B_2}{\Theta A_2}\left(f_{22}''(0) + \frac{2}{\bar{T}^*} f_{23}''(0) + \frac{2}{\bar{T}^*} T_W^* f_{24}''(0) \right) \right] \right\} \tag{87}$$

Heat Transfer - The heat transfer rate to the cone surface can be expressed (dimensional) as

$$q = -k_w \left(\frac{\partial T}{\partial y} \right)_w \tag{88}$$

where

$$k_w = \frac{c_p \mu_w}{Pr}$$

In terms of quantities presented in this report, equation (88) can be expressed to first order in ϵ as

$$q = -\frac{\bar{\rho}\bar{u}^3}{2 Pr}\sqrt{\frac{3G}{Re_x}} \left(1 + \epsilon \frac{(\Theta P_2)}{2} \cos\phi \right) T_\lambda^*(0,\phi) \tag{89}$$

The heat transfer coefficient $\hat{h}(x)$ is defined by

$$q = (T_w - T_{aw})\,\hat{h}(x) \tag{90}$$

or using (88)

$$\hat{h}(x) = \frac{\bar{\rho}\,\bar{u}^3}{T_{aw} - T_w}\sqrt{\frac{3C}{Re_x}}\left(1 + \epsilon\left(\frac{\Theta P_2}{2}\right)\cos\phi\right) T_\lambda^*(0,\phi) \tag{91}$$

Denoting the heat transfer coefficient at zero angle of attack, by $\hat{h}_1(x)$, we can write, in terms of the tabulated results,

$$\frac{\hat{h}}{\hat{h}_1} = 1 + \epsilon\cos\phi + \left[A_2\left\{\frac{\Theta P_2}{2A_2} + \frac{1}{(T_w^* - \bar{T}^*)\,T_{11}'(0) + T_{12}'(0)}\left[\frac{D_2}{A_2}\,T_{11}'(0)\right.\right.\right.$$

$$+ (T_w^* - \bar{T}^*)\left[T_{21}'(0) + \frac{2B_2}{\Theta A_2}\left(T_{22}'(0) + \frac{2}{\bar{T}^*}\,T_{23}'(0) + \frac{2}{\bar{T}^*}\,T_w^*\,T_{24}'(0)\right)\right]$$

$$\left.\left.\left. + T_{25}'(0) + \frac{2B_2}{\Theta A_2}\left(T_{26}'(0) + \frac{2}{\bar{T}^*}\,T_{27}'(0) + \frac{2}{\bar{T}^*}\,T_w^*\,T_{28}'(0)\right)\right]\right\} + \frac{D_2}{T_{aw_1}^* - T_w^*}\right\} \tag{92}$$

$$\left.\left. 1 + \frac{A_2}{D_2}\left(\tilde{T}_{21}(0) + \frac{2B_2}{\Theta A_2}\left[\frac{2}{\bar{T}^*}\,\tilde{T}_{22}(0) + \tilde{T}_{23}(0)\right]\right)\right\}\right]$$

where T_{aw}^* is the dimensionless adiabatic wall temperature defined by equation (80).

The local heat transfer coefficient can also be written in terms of the local Nusslet number.

Define

$$Nu_x = \frac{\hat{h}(x)\,x}{3\,k_w}\,\frac{T_w}{\bar{T}} \tag{93}$$

substituting equations (91), (26c), (39), and (42) into (93) gives

$$\frac{Nu_x}{\sqrt{\frac{Re_x}{3G}}} = \frac{1}{T_{AW}^* - T_w^*}\left\{ - T_{12}'(0) - (T_w^* - \bar{T}^*)\,T_{11}'(0) - \epsilon A_2 \cos\phi \right.$$

$$\left[\frac{D_2}{A_2}\,T_{11}'(0) + (T_w^* - \bar{T}^*)\left[\,T_{21}'(0) + \frac{2B_2}{\Theta A_2}\left(T_{22}'(0)\right.\right.\right.$$

$$\left.\left.\left. + \frac{2}{\bar{T}^*}\,T_{23}'(0) + \frac{2}{\bar{T}^*}\,T_w^*\,T_{24}'(0)\right)\right] + T_{25}'(0) + \frac{2B_2}{\Theta A_2}\left(T_{26}'(0)\right.$$

$$\left. + \frac{2}{\bar{T}^*}\,T_{27}'(0) + \frac{2}{\bar{T}^*}\,T_w^*\,T_{28}'(0)\right) - \frac{\Theta P_2}{2A_2}\left(T_{12}'(0)\right.$$

$$\left.\left. + (T_w^* - \bar{T}^*)\,T_{11}'(0)\right)\right]\Bigg\} \qquad (94)$$

Temperature Recovery Factor:

For a calorically perfect gas the recovery factor can be defined as

$$r_f = \frac{T_{AW}^* - T_e^*}{T_{0\infty}^* - T_e^*} \qquad (95)$$

where $T_{0\infty}^*$ is the non-dimensionalized free stream total temperature. By combining equations (4d) and (80) we find that to first order in ϵ, the recovery factor can be expressed as

$$r_f = \frac{1}{T_{0\infty}^* - \bar{T}^*}\,\tilde{T}_{11}(0) - \epsilon D_2 \cos\phi\left[\frac{1}{T_{0\infty}^* - \bar{T}^*}\left[\frac{A_2}{D_2}\left(\tilde{T}_{21}(0) + \frac{2B_2}{\Theta A_2}\left\{\frac{2}{\bar{T}^*}\,\tilde{T}_{22}(0)\right.\right.\right.\right.$$

$$\left.\left.\left.\left.\tilde{T}_{23}(0)\right\}\right)\right] + \frac{1}{(T_{0\infty}^* - \bar{T}^*)^2}\,\tilde{T}_{11}(0)\right] \qquad (96)$$

V RESULTS AND COMPARISON WITH EXPERIMENT

The results of the previous section can now be used to determine the velocity and temperature profiles, heat transfer rates, and other boundary layer characteristics for representative cones in supersonic flow.

Tracy (Ref. 12) measured the heat transfer rates around a yawed, 10° semivertex angle, pointed, right circular cone in a free stream Mach number eight flow. Most of the data was taken at a Reynolds number of 4×10^5 (based on distance from the apex), and a wall temperature ratio ($T_w/T_{t\infty}$) of 0.4. The yaw angle was varied from zero to 24°. The wall temperature was maintained at a constant value within the bounds of experimental error.

A comparison between the present theory and the experiments of Tracy can be made with the aid of equation (92). With the free stream conditions given in Tracy's report in Table II for Figure S5, and the use of equations (5) and Sims Tables, the coefficients appearing in equation (92) can be calculated. Using the results of Table I for a Prandtl number of 0.72, the local heat transfer rate around the cone can be calculated for different values of the angle of attack. The results of these calculations are presented in Figure 2.

For angles of attack up to 6°, agreement between experiment and theory for the entire windward portion of the cone is quite good. Even for $\alpha = 16°$, the present theory overestimates the heat transfer rate only by 9.6%, not an unacceptable error considering the assumptions

made in the theory. Beyond this point the error increases, thus indicating a breakdown of the linear theory used in this report.

When considering the flow around the entire cone, however, Figure 2 shows that good agreement is obtained only for values of angle of attack up to 2°. By the time $\alpha = 3°$ there is a significant discrepancy between theory and experiment for $\phi = 120°$, and it gets worse for larger yaw angles. This deviation possibly indicates the onset of separation of the boundary layer from the cone surface, at which point the theory is no longer valid. One indication of the onset of separation is the vanishing of the shear stress at the wall, τ_w. In Figure 7, the skin friction coefficient is plotted versus the circumferential cone angle for various yaw angles. The curves clearly show the skin friction approaching zero as the angle of attack is increased. Furthermore, for increasing α, the skin friction approaches zero for smaller circumferential cone angles. Thus, there is a qualitative relationship between the discrepancy of the theory and experiment for the local heat transfer rate and the vanishing of the shear stress at the wall. This, coupled with the fact that the heat transfer rate increases when the flow separates, enhances the possibility that separation of the flow has occurred.

Another possible explanation for this discrepancy is the inadequacy of the inviscid flow field theory near the leeward portion of the cone (see Ref. 12).

Figure 3 shows the heat transfer rate versus angle of attack in the most windward ($\phi = 0$) and leeward ($\phi = 180°$) planes of symmetry. The theory agrees favorably with Tracy's results in the windward plane of symmetry for all angles of attack, the maximum error being 9.6% for $\alpha = 16°$. In the leeward plane of symmetry, however, the theory fails for

angles of attack greater than six degrees.

The effect of the Prandtl number variation on the heat transfer rate due to angle of attack can be seen by considering Figure 6. On the windward portion of the cone, a Prandtl number of 0.72 results in a smaller heat transfer ratio than that occurring for Pr = 1.00, the difference between the two becoming more pronounced as the angle of attack increases. On the leeward side of the cone, however, the differences are quite small. In all cases the heat transfer varied roughly as $Pr^{0.31}$. The effect of Prandtl number on the velocity profiles was quite small and therefore was not explicitly displayed in Figure 4. Consequently the Prandtl number had a negligible effect on the skin friction.

Figure 8 shows the variation of the circumferential velocity ratio and the skin friction coefficient for insulated and noninsulated surfaces. The velocity ratio reaches a much higher maximum for the insulated wall than for the wall admitting heat transfer. Also, the skin friction coefficient is higher for the insulated surface on the windward portion of the cone and lower on the leeward side than for the non-insulated wall. In Figure 5 the static temperature profiles are plotted for insulated and noninsulated walls in the planes of symmetry.

Figures 2 and 3 show that the angle of attack has a significant effect on the heat transfer rate to the cone, causing an increase in heat transfer on the windward side and a decrease on the leeward side from that occurring at zero yaw. A similar effect is noted in

Figure 7 for the skin friction coefficient. Finally Figures 4 and 5 display the changes in the meridional velocity profile and the static temperature ratio which occur at angle of attack.

Figure 9 gives the variation of the temperature recovery factor, r_f, versus the angle of attack in the windward and leeward planes of symmetry for a Prandtl number of 0.72. At zero yaw, $r_f = 0.844$, a value which agrees quite closely with the accepted value of $r_f = Pr^{1/2}$ for laminar flow. The recovery factor increases slightly on the windward side and decreases slightly on the leeward side of the cone as the angle of attack is increased.

As mentioned in the introduction G.M. Low considered an equivalent analysis to the one presented in this report which was never published. However, Reshotko in reference 4 has tabulated in Table II several quantities from Low's analysis. The numbers in that report are given by the parameter ψ_w'', and are related to the shear in the circumferential direction. The equivalent parameter in this report is given by $g_2''(0)$, equation (40). For all applicable conditions given in Reshotko's report the maximum discrepancy between ψ_w'' and $g_2''(0)$ was found to be 0.0111, an error of 0.59%. A further check on the accuracy of the solutions presented in this report was made by comparing the insulated wall results with those obtained by Moore in reference 2. No significant differences appeared in comparing the present approach with Moore's results.

It should be remarked that this analysis will apply to any Mach number greater than one as long as we stay within the limits of ideal gas analysis and the Sims Tables.

VI. CONCLUSIONS

The governing equations for the compressible laminar boundary layer about a circular cone at a small angle of attack have been obtained by a perturbation of the flow at zero angle of attack. The form of the perturbation quantities was chosen to be compatible with the stream boundary conditions provided by the inviscid perturbation theory.

By the appropriate linear combination of terms, a set of ordinary differential equations for universal functions is obtained, and is solved once and for all, independent of any particular surface geometry and flow conditions. These functions are tabulated for both insulated and noninsulated surfaces for Prandtl numbers of 0.72 and 1.00.

Agreement between the theory and experimental data is found to be quite good in the most windward streamline for yaw angles up to 12°. When considering the flow around the entire cone discrepancies arise for angles of attack greater than 2°. This possibly indicates the onset of separation of the boundary layer.

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APPENDIX A

Numerical Integraion of Universal Functions

Each of the differential equations given by equations (43) through (60) for the heat transfer case, and (65) through (74) for the insulated wall case, constitutes a two-point boundary value problem. With the exception of Blasius equation (i.e. $f_1(\lambda)$) all the equations are linear, and the superposition principle can be used to satisfy the boundary conditions at infinity.

The method can be summarized as follows (Ref. 14). Suppose

$$y''(x) + P(x)y'(x) + Q(x)y(x) = F(x) \qquad \text{(A-1)}$$

and $\qquad y(a) = A \quad , \quad y(b) = B \qquad a \le x \le b$

is the two-point boundary value problem under consideration.

Let u(x) be any solution of

$$u'' + Pu' + Qu = F$$

which satisfies the condition u(a) = A

Further, let v(x) be any nontrivial solution satisfying the homogeneous equation

$$v'' + Pv' + Qv = 0$$

satisfying $v(a) = 0$

then the solution to (A-1) is given by

$$y(x) = u(x) + \frac{B - u(b)}{v(b)} v(x) \qquad \text{(A-2)}$$

As long as P(x), Q(x), and F(x) are continuous in (a,b), the initial slopes $u'(a)$ and $v'(a)$ are chosen arbitrarily as long as $v'(a) \neq 0$.

The Blasius equation was integrated using an Adams-Moulton integration scheme using one correction per step, while the linear equations were integrated using a Forth-Order Runge-Kutta method. For all equations a fixed step size of 0.02 was used.

APPENDIX B

Explanation of Tables

The following tables are reproduced directly from the printed computer output. Hence some clarification is needed concerning the symbols given in the tables and those presented in the report.

In Tables I and II we have the following correspondence between the symbols:

LAMBDA $\equiv \lambda$

$F1 \equiv f_1$, $F1' \equiv f_1'$, $F1'' \equiv f_1''$

$T11 \equiv T_{11}$, $T11' \equiv T_{11}'$; $T12 \equiv T_{12}$, $T12' \equiv T_{12}'$

$G21 \equiv g_{21}$, $G21' \equiv g_{21}'$, $G21'' \equiv g_{21}''$; $G22 \equiv g_{22}$, $G22' \equiv g_{22}'$, $G22'' \equiv g_{22}''$

$G23 \equiv g_{23}$, $G23' \equiv g_{23}'$, $G23'' \equiv g_{23}''$; $F21 \equiv f_{21}$, $F21' \equiv f_{21}'$, $F21'' \equiv f_{21}''$

$F22 \equiv f_{22}$, $F22' \equiv f_{22}'$, $F22'' \equiv f_{22}''$; $F23 \equiv f_{23}$, $F23' \equiv f_{23}'$, $F23'' \equiv f_{23}''$

$F24 \equiv f_{24}$, $F24' \equiv f_{24}'$, $F24'' \equiv f_{24}''$; $T21 \equiv T_{21}$, $T21' \equiv T_{21}'$

$T22 \equiv T_{22}$, $T22' \equiv T_{22}'$; $T23 \equiv T_{23}$, $T23' \equiv T_{23}'$; $T24 \equiv T_{24}$, $T24' \equiv T_{24}'$

$T25 \equiv T_{25}$, $T25' \equiv T_{25}'$; $T26 \equiv T_{26}$, $T26' \equiv T_{26}'$

$T27 \equiv T_{27}$, $T27' \equiv T_{27}'$; $T28 \equiv T_{28}$, $T28' \equiv T_{28}'$

In Tables III and IV

LAMBDA $\equiv \lambda$

$\tilde{F}1 \equiv \tilde{f}_1$, $\tilde{F}1' \equiv \tilde{f}_1'$, $\tilde{F}1'' \equiv \tilde{f}_1''$; $\tilde{T}11 \equiv \tilde{T}_{11}$, $\tilde{T}11' \equiv \tilde{T}_{11}'$

$\tilde{G}21 \equiv \tilde{g}_{21}$, $\tilde{G}21' \equiv \tilde{g}_{21}'$, $\tilde{G}21'' \equiv \tilde{g}_{21}''$; $\tilde{G}22 \equiv \tilde{g}_{22}$, $\tilde{G}22' \equiv \tilde{g}_{22}'$, $\tilde{G}22'' \equiv \tilde{g}_{22}''$

$\tilde{F}21 \equiv \tilde{f}_{21}$, $\tilde{F}21' \equiv \tilde{f}_{21}'$, $\tilde{F}21'' \equiv \tilde{f}_{21}''$; $\tilde{F}22 \equiv \tilde{f}_{22}$, $\tilde{F}22' \equiv \tilde{f}_{22}'$, $\tilde{F}22'' \equiv \tilde{f}_{22}''$

$\tilde{F}23 \equiv \tilde{f}_{23}$, $\tilde{F}23' \equiv \tilde{f}_{23}'$, $\tilde{F}23'' \equiv \tilde{f}_{23}''$; $\tilde{T}21 \equiv \tilde{T}_{21}$, $\tilde{T}21' \equiv \tilde{T}_{21}'$

$\tilde{T}22 \equiv \tilde{T}_{22}$, $\tilde{T}22' \equiv \tilde{T}_{22}'$; $\tilde{T}23 \equiv \tilde{T}_{23}$, $\tilde{T}23' \equiv \tilde{T}_{23}'$

TABLE I.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	F1	F1'	F1''	T11	T11'
.00000000	.00000000	.00000000	.33205733+000	.00000000	.29563624+000
.20000000+000	.66409995-002	.66407790-001	.33198383+000	.59124812-001	.29558863+000
.39999999+000	.26559883-001	.13276415+000	.33146983+000	.11821663+000	.29525905+000
.59999999+000	.59734636-001	.19893724+000	.33007912+000	.17719089+000	.29436660+000
.79999999+000	.10610821+000	.26470913+000	.32738926+000	.23590746+000	.29263746+000
.99999999+000	.16557172+000	.32978002+000	.32300711+000	.29417273+000	.28981191+000
.12000000+001	.23794871+000	.39377609+000	.31658918+000	.35174334+000	.28565426+000
.14000000+001	.32298156+000	.45626175+000	.30786538+000	.40833221+000	.27996475+000
.16000000+001	.42032075+000	.51675677+000	.29666345+000	.46361692+000	.27259234+000
.18000000+001	.52951802+000	.57475813+000	.28293101+000	.51725080+000	.26344717+000
.20000000+001	.65002435+000	.62976572+000	.26675154+000	.56887622+000	.25251113+000
.21999999+001	.78119332+000	.68131036+000	.24835091+000	.61813974+000	.23984511+000
.24000000+001	.92229010+000	.72898192+000	.22809175+000	.66470824+000	.22559135+000
.25999999+001	.10725059+001	.77245500+000	.20645462+000	.70828495+000	.20997000+000
.28000000+001	.12309772+001	.81150961+000	.18400659+000	.74862419+000	.19326961+000
.30000000+001	.13968082+001	.84604443+000	.16136031+000	.78554356+000	.17583170+000
.32000000+001	.15690949+001	.87608144+000	.13912805+000	.81893266+000	.15803094+000
.33999999+001	.17469500+001	.90176120+000	.11787624+000	.84875745+000	.14025245+000
.36000000+001	.19295251+001	.92332965+000	.98086278-001	.87506003+000	.12286875+000
.37999999+001	.21160297+001	.94111798+000	.80125918-001	.89795396+000	.10621848+000
.39999999+001	.23057463+001	.95551821+000	.64234121-001	.91761562+000	.90588883-001
.41999999+001	.24980396+001	.96695706+000	.50519748-001	.93427263+000	.76203617-001
.43999999+001	.26923608+001	.97587081+000	.38972611-001	.94819043+000	.63216490-001
.45999999+001	.28882479+001	.98268348+000	.29483772-001	.95965815+000	.51711047-001
.47999999+001	.30853206+001	.98778951+000	.21871187-001	.96897496+000	.41705336-001
.49999999+001	.32832736+001	.99154188+000	.15906799-001	.97643779+000	.33160659-001
.51999999+001	.34818675+001	.99424552+000	.11341789-001	.98233109+000	.25992872-001
.54000000+001	.36809190+001	.99615529+000	.79276602-002	.98691897+000	.20084820-001
.56000000+001	.38802906+001	.99747775+000	.54319580-002	.99043983+000	.15298616-001
.57999999+001	.40798818+001	.99837548+000	.36484139-002	.99310337+000	.11486785-001
.59999999+001	.42796208+001	.99897286+000	.24020400-002	.99508964+000	.85016126-002
.61999999+001	.44794572+001	.99936252+000	.15501708-002	.99654972+000	.62023578-002
.63999999+001	.46793565+001	.99961168+000	.98061518-003	.99760769+000	.44602843-002
.65999999+001	.48792957+001	.99976785+000	.60804429-003	.99836336+000	.31616727-002
.67999999+001	.50792597+001	.99986380+000	.36956258-003	.99889539+000	.22091180-002
.69999999+001	.52792387+001	.99992159+000	.22016895-003	.99926463+000	.15214859-002
.71999999+001	.54792267+001	.99995570+000	.12856980-003	.99951723+000	.10329127-002
.74000000+001	.56792200+001	.99997544+000	.73592973-004	.99968756+000	.69120327-003
.75999999+001	.58792163+001	.99998664+000	.41290301-004	.99980079+000	.45592587-003
.77999999+001	.60792143+001	.99999286+000	.22707743-004	.99987497+000	.29643463-003
.79999999+001	.62792133+001	.99999626+000	.12240919-004	.99992288+000	.18998085-003
.82000000+001	.64792127+001	.99999807+000	.64679739-005	.99995338+000	.12001538-003
.84000000+001	.66792125+001	.99999902+000	.33499364-005	.99997252+000	.74732614-004
.86000000+001	.68792123+001	.99999951+000	.17006657-005	.99998436+000	.45870090-004
.88000000+001	.70792123+001	.99999975+000	.84628270-006	.99999158+000	.27752056-004
.90000000+001	.72792122+001	.99999987+000	.41278702-006	.99999592+000	.16550338-004
.92000000+001	.74792122+001	.99999993+000	.19735615-006	.99999849+000	.97289231-005
.94000000+001	.76792122+001	.99999996+000	.92488849-007	.99999999+000	.56372696-005

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	T12	T12'	G21	G21'	G21''
.00000000	.00000000	-.24955533+000	.00000000	.00000000	.37085086-001
.20000000+000	-.46733798-001	-.21776783+000	.73864804-003	.73581504-002	.36239272-001
.39999999+000	-.87098006-001	-.18584945+000	.29221093-002	.14400563-001	.33966484-001
.59999999+000	-.12106640+000	-.15382916+000	.64602618-002	.20365395-001	.30503788-001
.79999999+000	-.14863596+000	-.12190859+000	.11215423-001	.26539237-001	.26098801-001
.99999999+000	-.16986040+000	-.90451113-001	.17012255-001	.31259303-001	.21009848-001
.12000000+001	-.18488058+000	-.59959669-001	.23648087-001	.34915289-001	.15502567-001
.14000000+001	-.19394898+000	-.31040608-001	.30903516-001	.37450211-001	.98431849-002
.16000000+001	-.19744562+000	-.43531127-002	.38553027-001	.38859623-001	.42890166-002
.18000000+001	-.19588251+000	.19452806-001	.46375245-001	.39188710-001	-.92288922-003
.20000000+001	-.18989516+000	.39803716-001	.54162378-001	.38527042-001	-.55876674-002
.21999999+001	-.18022065+000	.56266926-001	.61728375-001	.37001017-001	-.95436002-002
.24000000+001	-.16766412+000	.68601704-001	.68915370-001	.34764326-001	-.12680583-001
.25999999+001	-.15305698+000	.76788927-001	.75598059-001	.31987097-001	-.14944781-001
.28000000+001	-.13721182+000	.81033835-001	.81685867-001	.28844554-001	-.16338632-001
.30000000+001	-.12087961+000	.81741369-001	.87122858-001	.25506169-001	-.16916038-001
.32000000+001	-.10471415+000	.79468784-001	.91885613-001	.22126217-001	-.16773283-001
.33999999+001	-.89247615-001	.74864268-001	.95979419-001	.18836471-001	-.16036857-001
.36000000+001	-.74878871-001	.68602181-001	.99433253-001	.15741524-001	-.14849775-001
.37999999+001	-.61874244-001	.61324896-001	.10229411+000	.12916847-001	-.13358091-001
.39999999+001	-.50378621-001	.53598409-001	.10462119+000	.10409400-001	-.11699116-001
.41999999+001	-.40433742-001	.45885102-001	.10648047+000	.82403284-002	-.99924370-002
.43999999+001	-.32000226-001	.38533332-001	.10793989+000	.64091330-002	-.83342733-002
.45999999+001	-.24980237-001	.31780324-001	.10906553+000	.48986243-002	-.67951845-002
.47999999+001	-.19238437-001	.25767509-001	.10991881+000	.36800371-002	-.54206751-002
.49999999+001	-.14619815-001	.20553426-001	.11055464+000	.27177927-002	-.42339774-002
.51999999+001	-.10953727-001	.16138020-001	.11102046+000	.19735563-002	-.32401757-002
.54000000+001	-.81141664-002	.12478339-001	.11135606+000	.14094025-002	-.24308763-002
.56000000+001	-.59266236-002	.95047111-002	.11159387+000	.99004840-003	-.17887755-002
.57999999+001	-.42721229-002	.71333168-002	.11175964+000	.68422217-003	-.12916722-002
.59999999+001	-.30390505-002	.52756903-002	.11187334+000	.46530725-003	-.91567592-003
.61999999+001	-.21333701-002	.38454310-002	.11195009+000	.31143323-003	-.63753096-003
.63999999+001	-.14777371-002	.27625879-002	.11200108+000	.20518641-003	-.43611166-003
.65999999+001	-.10099283-002	.19561832-002	.11203443+000	.13309405-003	-.29321699-003
.67999999+001	-.68091683-003	.13653235-002	.11205591+000	.85005856-004	-.19383196-003
.69999999+001	-.45283176-003	.93929104-003	.11206953+000	.53462387-004	-.12602234-003
.71999999+001	-.29697325-003	.63695209-003	.11207804+000	.33108961-004	-.80609488-004
.74000000+001	-.19199133-003	.42575249-003	.11208327+000	.20196462-004	-.50740786-004
.75999999+001	-.12228851-003	.28051265-003	.11208643+000	.12111459-004	-.31437992-004
.77999999+001	-.76670261-004	.18217680-003	.11208832+000	.71443326-005	-.19175114-004
.79999999+001	-.47240958-004	.11662167-003	.11208942+000	.41363992-005	-.11513468-004
.82000000+001	-.28526626-004	.73598717-004	.11209005+000	.23433647-005	-.68038571-005
.84000000+001	-.16795981-004	.45770849-004	.11209041+000	.12916770-005	-.39545179-005
.86000000+001	-.95479061-005	.28061606-004	.11209060+000	.68531411-006	-.22572631-005
.88000000+001	-.51334551-005	.16958284-004	.11209070+000	.34236919-006	-.12615735-005
.90000000+001	-.24832227-005	.10101762-004	.11209075+000	.15290279-006	-.68615690-006
.92000000+001	-.91486747-006	.59314137-005	.11209077+000	.51536563-007	-.35851614-006
.94000000+001	.00000000	.34329314-005	.11209077+000	.00000000	-.17469405-006

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	G22	G22'	G22''	G23	G23'	G23''
.00000000	.00000000	.00000000	.17863453+000	.00000000	.00000000	.70523121-001
.20000000+000	.33542139-002	.32466479-001	.14636610+000	.14032594-002	.13965921-001	.68533922-001
.39999999+000	.12569973-001	.58684513-001	.11616985+000	.55368762-002	.27193595-001	.63245577-001
.59999999+000	.26439873-001	.79081352-001	.88178229-001	.12191446-001	.39086778-001	.55297269-001
.79999999+000	.43844754-001	.94112875-001	.62542793-001	.21051238-001	.49179168-001	.45349453-001
.99999999+000	.63759724-001	.10426597+000	.39419500-001	.31720604-001	.57138449-001	.34080053-001
.12000000+001	.85250333-001	.11005784+000	.18952806-001	.43751042-001	.62768590-001	.22170996-001
.14000000+001	.10752830+000	.11203207+000	.12593487-002	.56668409-001	.66008570-001	.10286146-001
.16000000+001	.12985615+000	.11075147+000	-.13587669-001	.69999373-001	.66925996-001	-.95720734-003
.18000000+001	.15165004+000	.10678800+000	-.25572023-001	.83296003-001	.65704635-001	-.11020099-001
.20000000+001	.17243043+000	.10071028+000	-.34744508-001	.96157219-001	.62625616-001	-.19472685-001
.21999999+001	.19183003+000	.93069617-001	-.41228171-001	.10824590+000	.58042951-001	-.26019520-001
.24000000+001	.20958881+000	.84385435-001	-.45217809-001	.11930067+000	.52354910-001	-.30515017-001
.25999999+001	.22554634+000	.75131550-001	-.46973381-001	.12914168+000	.45973566-001	-.32966958-001
.28000000+001	.23963135+000	.65724244-001	-.46807730-001	.13767039+000	.39295265-001	-.33519738-001
.30000000+001	.25184929+000	.56513318-001	-.45069715-001	.14486378+000	.32674796-001	-.32439356-001
.32000000+001	.26226847+000	.47776829-001	-.42124489-001	.15076390+000	.26405656-001	-.30068299-001
.33999999+001	.27100548+000	.39719886-001	-.38333018-001	.15546431+000	.20707945-001	-.26790169-001
.36000000+001	.27821086+000	.32477435-001	-.34033009-001	.15909485+000	.15724405-001	-.22988562-001
.37999999+001	.28405562+000	.26120560-001	-.29523119-001	.16180642+000	.11524022-001	-.19012341-001
.39999999+001	.28871931+000	.20665491-001	-.25051777-001	.16375711+000	.81116980-002	-.15150132-001
.41999999+001	.29238014+000	.16084332-001	-.20811277-001	.16510058+000	.54419240-002	-.11615955-001
.43999999+001	.29520730+000	.12316443-001	-.16937036-001	.16597806+000	.34342096-002	-.85459276-002
.45999999+001	.29735548+000	.92795129-002	-.13511312-001	.16651183+000	.19881942-002	-.60042698-002
.47999999+001	.29896158+000	.68795232-002	-.10570275-001	.16680364+000	.99585750-003	-.39958124-002
.49999999+001	.30014325+000	.50190857-002	-.81130822-002	.16693396+000	.35684171-003	-.24818581-002
.51999999+001	.30099868+000	.36038643-002	-.61116855-002	.16696359+000	-.24485269-004	-.13964787-002
.54000000+001	.30160867+000	.25470586-002	-.45202682-002	.16693618+000	-.22508422-003	-.66108550-003
.56000000+001	.30203646+000	.17721064-002	-.32835194-002	.16688144+000	-.30691894-003	-.19591913-003
.57999999+001	.30233193+000	.12138879-002	-.23432869-002	.16681820+000	-.31657422-003	.72027709-004
.59999999+001	.30253287+000	.81877717-003	-.16434489-002	.16675739+000	-.28711085-003	.20449062-003
.61999999+001	.30266744+000	.54389216-003	-.11330871-002	.16670448+000	-.24053137-003	.25022661-003
.63999999+001	.30275620+000	.35586059-003	-.76820308-003	.16666140+000	-.19037029-003	.24534019-003
.65999999+001	.30281387+000	.22936199-003	-.51229660-003	.16662806+000	-.14408181-003	.21485864-003
.67999999+001	.30285078+000	.14563970-003	-.33614277-003	.16660328+000	-.10504451-003	.17489046-003
.69999999+001	.30287406+000	.91111783-004	-.21707150-003	.16658550+000	-.74118543-004	.13487537-003
.71999999+001	.30288852+000	.56154681-004	-.13799755-003	.16657313+000	-.50770939-004	.99615423-004
.74000000+001	.30289738+000	.34089976-004	-.86383467-004	.16656476+000	-.33430164-004	.70952096-004
.75999999+001	.30290271+000	.20374857-004	-.53255189-004	.16655926+000	-.21952089-004	.48809358-004
.77999999+001	.30290588+000	.11978189-004	-.32338000-004	.16655573+000	-.13874528-004	.32754910-004
.79999999+001	.30290773+000	.69147696-005	-.19340782-004	.16655353+000	-.85335875-005	.21348666-004
.82000000+001	.30290878+000	.39075965-005	-.11390203-004	.16655219+000	-.50943772-005	.13557782-004
.84000000+001	.30290937+000	.21494211-005	-.66006437-005	.16655140+000	-.29359314-005	.83918090-005
.86000000+001	.30290969+000	.11384976-005	-.37583134-005	.16655096+000	-.16159651-005	.50577920-005
.88000000+001	.30290986+000	.56804517-006	-.20962320-005	.16655072+000	-.83081937-006	.29593578-005
.90000000+001	.30290994+000	.25346264-006	-.11383253-005	.16655061+000	-.37962455-006	.16693109-005
.92000000+001	.30290997+000	.85385447-007	-.59413601-006	.16655056+000	-.12901354-006	.89374377-006
.94000000+001	.30290997+000	.00000000	-.28938394-006	.16655055+000	-.86736173-018	.43736718-006

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	F21	F21'	F21''	F22	F22'	F22''
.00000000	.00000000	.00000000	.49809172+000	.00000000	.00000000	.62172667-001
.20000000+000	.99613528-002	.99606525-001	.49785966+000	.12433229-002	.12431359-001	.62110903-001
.39999999+000	.39832614-001	.19905431+000	.49628505+000	.49699113-002	.24820957-001	.61698347-001
.59999999+000	.89546456-001	.29794419+000	.49206720+000	.11162146-001	.37064969-001	.60600592-001
.79999999+000	.15893002+000	.39562219+000	.48396863+000	.19775072-001	.48994594-001	.58505314-001
.99999999+000	.24765569+000	.49119875+000	.47088407+000	.30723978-001	.60382523-001	.55143836-001
.12000000+001	.35519709+000	.58358377+000	.45192962+000	.43873739-001	.70954272-001	.50317832-001
.14000000+001	.48079417+000	.67154078+000	.42654183+000	.59030979-001	.80405108-001	.43927794-001
.16000000+001	.62343089+000	.75376064+000	.39457251+000	.75940177-001	.88422460-001	.35998587-001
.18000000+001	.78182963+000	.82895251+000	.35636163+000	.94284717-001	.94712699-001	.26696616-001
.20000000+001	.95446481+000	.89594545+000	.31275987+000	.11369356+000	.99030055-001	.16333282-001
.21999999+001	.11395973+001	.95379139+000	.26515599+000	.13375365+000	.10120451+000	.53507344-002
.24000000+001	.13353285+001	.10018571+001	.21529089+000	.15402751+000	.10116493+000	-.57113958-002
.25999999+001	.15396706+001	.10398933+001	.16521178+000	.17407460+000	.98953920-001	-.16286048-001
.28000000+001	.17506275+001	.10680687+001	.11703129+000	.19347466+000	.94730771-001	-.25739586-001
.30000000+001	.19662766+001	.10869650+001	.72727683-001	.21185043+000	.88763525-001	-.33634545-001
.32000000+001	.21848574+001	.10975292+001	.33947552-001	.22888733+000	.81407026-001	-.39564183-001
.33999999+001	.24048164+001	.11009910+001	.18522587-002	.24434803+000	.73073205-001	-.43369762-001
.36000000+001	.26248739+001	.10987563+001	-.22968910-001	.25808038+000	.64195558-001	-.45934649-001
.37999999+001	.28440370+001	.10922901+001	-.40508304-001	.27001806+000	.55193379-001	-.44673796-001
.39999999+001	.30616024+001	.10830053+001	-.51276445-001	.28017450+000	.46440331-001	-.42601772-001
.41999999+001	.32771363+001	.10721709+001	-.56182473-001	.28863129+000	.38240983-001	-.39206449-001
.43999999+001	.34904386+001	.10608462+001	-.56383399-001	.29552280+000	.30817355-001	-.34916791-001
.45999999+001	.37014971+001	.10498477+001	-.53128906-001	.30101921+000	.24305729-001	-.30153606-001
.47999999+001	.39104379+001	.10397443+001	-.47624729-001	.30530979+000	.18762438-001	-.25990014-001
.49999999+001	.41174776+001	.10308767+001	-.40930097-001	.30858810+000	.14176276-001	-.20625204-001
.51999999+001	.43228813+001	.10233944+001	-.33895886-001	.31104002+000	.10484680-001	-.16372657-001
.54000000+001	.45269281+001	.10172992+001	-.27142041-001	.31283521+000	.75909815-002	-.12561035-001
.56000000+001	.47298870+001	.10124919+001	-.21067038-001	.31412196+000	.53804724-002	-.95443397-002
.57999999+001	.49320001+001	.10088129+001	-.15879208-001	.31502497+000	.37538100-002	-.70179097-002
.59999999+001	.51334750+001	.10060767+001	-.11639392-001	.31564545+000	.25370066-002	-.50336053-002
.61999999+001	.53344812+001	.10040966+001	-.83059149-002	.31606292+000	.16879316-002	-.35276144-002
.63999999+001	.55351526+001	.10027008+001	-.57754216-002	.31633798+000	.10997029-002	-.24155141-002
.65999999+001	.57355906+001	.10017417+001	-.39158903-002	.31651545+000	.70142107-003	-.16152323-002
.67999999+001	.59358703+001	.10010988+001	-.25905065-002	.31662758+000	.43437987-003	-.10537651-002
.69999999+001	.61360449+001	.10006783+001	-.16728629-002	.31669698+000	.26824051-003	-.67281734-003
.71999999+001	.63361517+001	.10004098+001	-.10549650-002	.31673904+000	.16073641-003	-.42001164-003
.74000000+001	.65362156+001	.10002422+001	-.64993735-003	.31676400+000	.94315748-004	-.25633259-003
.75999999+001	.67362530+001	.10001401+001	-.39128440-003	.31677850+000	.54181357-004	-.15306778-003
.77999999+001	.69362744+001	.10000792+001	-.23025830-003	.31678676+000	.30460122-004	-.89392893-004
.79999999+001	.71362863+001	.10000438+001	-.13247660-003	.31679135+000	.16744160-004	-.51074635-004
.82000000+001	.73362929+001	.10000236+001	-.74533476-004	.31679385+000	.89345564-005	-.28552501-004
.84000000+001	.75362964+001	.10000123+001	-.41013680-004	.31679517+000	.46489049-005	-.15419525-004
.86000000+001	.77362982+001	.10000062+001	-.22076970-004	.31679585+000	.23616727-005	-.83621897-005
.88000000+001	.79362991+001	.10000030+001	-.11626376-004	.31679619+000	.11276775-005	-.43815795-005
.90000000+001	.81362995+001	.10000013+001	-.59909794-005	.31679634+000	.48722291-006	-.22473237-005
.92000000+001	.83362997+001	.10000004+001	-.30209868-005	.31679640+000	.16183679-006	-.11263104-005
.94000000+001	.85362997+001	.10000000+001	-.14908762-005	.31679642+000	-.10942021-018	-.55457455-006

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	F23	F23'	F23''	F24	F24'	F24''
.00000000	.00000000	.00000000	.39348259-002	.00000000	.00000000	.12465721-001
.20000000+000	.78686243-004	.78671561-003	.39299779-002	.24927216-003	.24921234-002	.12446044-001
.39999999+000	.31448032-003	.15701667-002	.38978042-002	.99602925-003	.49712976-002	.12320088-001
.59999999+000	.70601025-003	.23423140-002	.38128750-002	.22349367-002	.74071165-002	.11999108-001
.79999999+000	.12498029-002	.30902764-002	.36524989-002	.39529195-002	.97531833-002	.11412504-001
.99999999+000	.19393829-002	.37970685-002	.33986761-002	.61263506-002	.11951112-001	.10511690-001
.12000000+001	.27645596-002	.44427510-002	.30402112-002	.87191226-002	.13935357-001	.92743509-002
.14000000+001	.37109861-002	.50059910-002	.25746573-002	.11681766-001	.15638846-001	.77079855-002
.16000000+001	.47600658-002	.54659631-002	.20096970-002	.14951758-001	.16999152-001	.58516519-002
.18000000+001	.58892612-002	.58044370-002	.13635719-002	.18455077-001	.17964754-001	.37749001-002
.20000000+001	.70728209-002	.60078292-002	.66425922-003	.22108972-001	.18500747-001	.15732720-002
.21999999+001	.82828914-002	.60689539-002	-.52718652-004	.25825759-001	.18593291-001	-.63971380-003
.24000000+001	.94909264-002	.59882077-002	-.74771473-003	.29517323-001	.18252156-001	-.27454770-002
.25999999+001	.10669258-001	.57739793-002	-.13812008-002	.33099898-001	.17510897-001	-.46226959-002
.28000000+001	.11792666-001	.54421787-002	-.19182098-002	.36498635-001	.16424506-001	-.61806499-002
.30000000+001	.12839756-001	.50149185-002	-.23322574-002	.39651455-001	.15064779-001	-.73474599-002
.32000000+001	.13794019-001	.45185184-002	-.26080889-002	.42511802-001	.13513984-001	-.80865895-002
.33999999+001	.14644431-001	.39811169-002	-.27428128-002	.45050024-001	.11857692-001	-.84056241-002
.36000000+001	.15385573-001	.34302307-002	-.27453039-002	.47253323-001	.10177740-001	-.83334661-002
.37999999+001	.16017283-001	.28905901-002	-.26340932-002	.49124380-001	.85462107-002	-.79335104-002
.39999999+001	.16543926-001	.23825103-002	-.24342268-002	.50678939-001	.70211011-002	-.72830979-002
.41999999+001	.16973401-001	.19209414-002	-.21737140-002	.51942725-001	.56440110-002	-.64671826-002
.43999999+001	.17316037-001	.15152197-002	-.18801685-002	.52948104-001	.44398306-002	-.55668690-002
.45999999+001	.17583494-001	.11694302-002	-.15781144-002	.53730851-001	.34141295-002	-.46530501-002
.47999999+001	.17787788-001	.88321711-003	-.12872215-002	.54327332-001	.25757484-002	-.37915896-002
.49999999+001	.17940509-001	.65284961-003	-.10215193-002	.54772275-001	.19000320-002	-.29915017-002
.51999999+001	.18052255-001	.47235500-003	-.78946805-003	.55097208-001	.13721761-002	-.23055158-002
.54000000+001	.18132299-001	.33457132-003	-.59465445-003	.55329544-001	.97028075-003	-.17323407-002
.56000000+001	.18188432-001	.23202019-003	-.43684789-003	.55492215-001	.67184354-003	-.12698637-002
.57999999+001	.18226977-001	.15755347-003	-.31317033-003	.55603754-001	.45557865-003	-.90859686-003
.59999999+001	.18252897-001	.10477058-003	-.21919418-003	.55678657-001	.30256642-003	-.63485410-003
.61999999+001	.18269966-001	.68233738-004	-.14985065-003	.55727925-001	.19682207-003	-.43334696-003
.63999999+001	.18280977-001	.43525290-004	-.10009844-003	.55759668-001	.12541565-003	-.28907061-003
.65999999+001	.18287933-001	.27195397-004	-.65353929-004	.55779704-001	.78294996-004	-.18849769-003
.67999999+001	.18292239-001	.16644927-004	-.41716728-004	.55792092-001	.47870912-004	-.12016573-003
.69999999+001	.18294849-001	.99796000-005	-.26040311-004	.55799596-001	.28677398-004	-.74944772-004
.71999999+001	.18296399-001	.58611978-005	-.15898995-004	.55804050-001	.16829720-004	-.45714712-004
.74000000+001	.18297301-001	.33718924-005	-.94964193-005	.55806639-001	.96750375-005	-.27281691-004
.75999999+001	.18297815-001	.18997700-005	-.55499164-005	.55808114-001	.54474177-005	-.15931363-004
.77999999+001	.18298102-001	.10478642-005	-.31740293-005	.55808936-001	.30027966-005	-.91045628-005
.79999999+001	.18298259-001	.56538461-006	-.17765931-005	.55809385-001	.16192553-005	-.50926221-005
.82000000+001	.18298343-001	.29792521-006	-.97334385-006	.55809625-001	.85280063-006	-.27863429-005
.84000000+001	.18298386-001	.15278954-006	-.52202267-006	.55809749-001	.43714047-006	-.14945644-005
.86000000+001	.18298409-001	.75686912-007	-.27409196-006	.55809812-001	.21644826-006	-.7843031B-006
.88000000+001	.18298419-001	.35583625-007	-.14090366-006	.55809843-001	.10172075-006	-.40298396-006
.90000000+001	.18298424-001	.15159664-007	-.70924963-007	.55809857-001	.43320864-007	-.20274789-006
.92000000+001	.18298426-001	.49742317-008	-.34958731-007	.55809862-001	.14210384-007	-.99868924-007
.94000000+001	.18298426-001	-.13552527-019	-.16874004-007	.55809863-001	-.54210108-019	-.48194313-007

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	T21	T21'	T22	T22'	T23	T23'
.00000000	.00000000	.14773769+000	.00000000	.54927973-001	.00000000	.33048534-002
.20000000+000	.29542278-001	.14763581+000	.10983548-001	.54888355-001	.66081136-003	.33017715-002
.39999999+000	.59015750-001	.14695568+000	.21940362-001	.54624235-001	.13195514-002	.32813577-002
.59999999+000	.88248804-001	.14514015+000	.32803906-001	.53920450-001	.19711151-002	.32274052-002
.79999999+000	.11696045+000	.14165603+000	.43465582-001	.52572991-001	.26072925-002	.31252233-002
.99999999+000	.14476755+000	.13601985+000	.53777955-001	.50399503-001	.32171696-002	.29626417-002
.12000000+001	.17119799+000	.12783179+000	.63560376-001	.47252584-001	.37877412-002	.27310965-002
.14000000+001	.19571129+000	.11681448+000	.72607433-001	.43034477-001	.43047366-002	.24266607-002
.16000000+001	.21772700+000	.10285193+000	.80700327-001	.37711304-001	.47536343-002	.20508544-002
.18000000+001	.23666047+000	.86022764-001	.87620871-001	.31324626-001	.51208002-002	.16110693-002
.20000000+001	.25196413+000	.66621310-001	.93167327-001	.23997922-001	.53946622-002	.11204595-002
.21999999+001	.26317127+000	.45160571-001	.97170861-001	.15935946-001	.55668014-002	.59723584-003
.24000000+001	.26993821+000	.22352781-001	.99511026-001	.74155853-002	.56328405-002	.63334816-004
.25999999+001	.27208027+000	-.93367446-003	.10012855+000	-.12319310-002	.55930139-002	-.45739792-003
.28000000+001	.26959683+000	-.23738510-001	.99033806-001	-.96462342-002	.54523404-002	-.94132781-003
.30000000+001	.26268202+000	-.45088585-001	.96309650-001	-.17467826-001	.52203644-002	-.13671804-002
.32000000+001	.25171883+000	-.64082303-001	.92108159-001	-.24369251-001	.49104878-002	-.17179336-002
.33999999+001	.23725676+000	-.79968388-001	.86641290-001	-.30083390-001	.45389711-002	-.19822015-002
.36000000+001	.21997511+000	-.92208584-001	.80166510-001	-.34425168-001	.41237234-002	-.21549420-002
.37999999+001	.20063609+000	-.10051629+000	.72968972-001	-.37303997-001	.36830236-002	-.22374351-002
.39999999+001	.18003294+000	-.10486710+000	.65342248-001	-.38725781-001	.32343152-002	-.22365911-002
.41999999+001	.15893880+000	-.10548151+000	.57569666-001	-.38784904-001	.27931937-002	-.21637470-002
.43999999+001	.13806144+000	-.10278438+000	.49908131-001	-.37648081-001	.23726686-002	-.20331644-002
.45999999+001	.11800782+000	-.97348480-001	.42575721-001	-.35532889-001	.19827362-002	-.18604530-002
.47999999+001	.99260894-001	-.89830652-001	.35743887-001	-.32684168-001	.16302591-002	-.16611210-002
.49999999+001	.82169067-001	-.80999190-001	.29534295-001	-.29351315-001	.13191092-002	-.14493951-002
.51999999+001	.66947616-001	-.71229193-001	.24019934-001	-.25768852-001	.10505138-002	-.12373908-002
.54000000+001	.53689733-001	-.61360565-001	.19229639-001	-.22141803-001	.82352929-003	-.10346499-002
.56000000+001	.42384542-001	-.51770765-001	.15154995-001	-.18636553-001	.63557446-003	-.84801298-003
.57999999+001	.32939087-001	-.42812179-001	.11758549-001	-.15376909-001	.48296023-003	-.68175980-003
.59999999+001	.25201525-001	-.34722233-001	.89823124-002	-.12444787-001	.36137172-003	-.53793234-003
.61999999+001	.18983258-001	-.27633337-001	.67557914-002	-.98842458-002	.26627286-003	-.41677763-003
.63999999+001	.14078379-001	-.21589284-001	.50029578-002	-.77077320-002	.19321985-003	-.31720561-003
.65999999+001	.10279458-001	-.16554893-001	.36478515-002	-.59033564-002	.13808231-003	-.23724172-003
.67999999+001	.73893128-002	-.12486138-001	.26187092-002	-.44422281-002	.97190194-004	-.17441648-003
.69999999+001	.52288820-002	-.92487194-002	.18506806-002	-.32851397-002	.67349957-004	-.12607958-003
.71999999+001	.36416559-002	-.67337673-002	.12873116-002	-.23881647-002	.45956217-004	-.89631836-004
.74000000+001	.24953058-002	-.48200726-002	.88103542-003	-.17069688-002	.30964843-004	-.62679699-004
.75999999+001	.16812281-002	-.33927574-002	.59293037-003	-.11998314-002	.20392011-004	-.43123562-004
.77999999+001	.11126837-002	-.23487189-002	.39199390-003	-.82950960-003	.13241053-004	-.29193921-004
.79999999+001	.72212717-003	-.15993939-002	.25414155-003	-.56414978-003	.84360702-005	-.19449996-004
.82000000+001	.45819761-003	-.10714851-002	.16109957-003	-.37748326-003	.52594427-005	-.12754059-004
.84000000+001	.28271518-003	-.70628066-003	.99310970-004	-.24853287-003	.31499825-005	-.82323929-005
.86000000+001	.16790717-003	-.45811946-003	.58932260-004	-.16102758-003	.18545161-005	-.52311165-005
.88000000+001	.93989162-004	-.29243671-003	.32963196-004	-.10268098-003	.10283213-005	-.32725859-005
.90000000+001	.47149906-004	-.18372994-003	.16524744-004	-.64445443-004	.50392467-006	-.20158122-005
.92000000+001	.17955981-004	-.11362101-003	.62822987-005	-.39814612-004	.19125466-006	-.12226501-005
.94000000+001	.43368086-018	-.69167448-004	.00000000	-.24214388-004	-.68634904-010	-.73025633-006

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	T24	T24'	T25	T25'	T26	T26'
.00000000	.00000000	.10319010-001	.00000000	-.62335125+000	.00000000	-.46557005-001
.20000000+000	.20631510-002	.10306503-001	-.11513652+000	-.52795528+000	-.81208748-002	-.34640399-001
.39999999+000	.41180850-002	.10226587-001	-.21114861+000	-.43208357+000	-.13850179-001	-.22639783-001
.59999999+000	.61455009-002	.10022757-001	-.28795358+000	-.33599194+000	-.17175355-001	-.10630642-001
.79999999+000	.81158493-002	.96492649-002	-.34559746+000	-.24070479+000	-.18117460-001	.11483012-002
.99999999+000	.99916421-002	.90727843-002	-.38440290+000	-.14794755+000	-.16757184-001	.12313902-001
.12000000+001	.11730129-001	.82743458-002	-.40509713+000	-.60011603-001	-.13265405-001	.22375220-001
.14000000+001	.13286352-001	.72510585-002	-.40890498+000	.20461002-001	-.79169186-002	.30790005-001
.16000000+001	.14618475-001	.60171709-002	-.39759113+000	.90767414-001	-.10940826-002	.37038179-001
.18000000+001	.15841235-001	.46040445-002	-.37343888+000	.14848216+000	.67257697-002	.40703781-001
.20000000+001	.16949251-001	.30587198-002	-.33916030+000	.19179718+000	.14999060-001	.41551942-001
.21999999+001	.18099875-001	.14409408-002	-.29774292+000	.21980495+000	.23158291-001	.39585107-001
.24000000+001	.17025327-001	-.18126347-003	-.25225049+000	.23266702+000	.30662309-001	.35064435-001
.25999999+001	.18831804-001	-.17370820-002	-.20560496+000	.23162803+000	.37046662-001	.28458632-001
.28000000+001	.18339446-001	-.31589272-002	-.16038225+000	.21886609+000	.41965521-001	.20531992-001
.30000000+001	.15561101-001	-.43832229-002	-.11865225+000	.19720749+000	.45218045-001	.11953462-001
.32000000+001	.14600015-001	-.53802422-002	-.81884699-001	.16976398+000	.46755207-001	.34956928-002
.33999999+001	.13446705-001	-.61073881-002	-.50929427-001	.13956525+000	.46667174-001	-.42051841-002
.36000000+001	.12175366-001	-.65605484-002	-.25064760-001	.10925374+000	.45155158-001	-.10682467-001
.37999999+001	.10840204-001	-.67484585-002	-.70968176-002	.80886046-001	.42494186-001	-.15666253-001
.39999999+001	.94920801-002	-.66953053-002	.65135106-002	.55854366-001	.38993918-001	-.19076452-001
.41999999+001	.81757725-002	-.64370398-002	.15519873-001	.34913632-001	.34963528-001	-.20990041-001
.43999999+001	.69280558-002	-.60169962-002	.20767123-001	.18281802-001	.30685304-001	-.21594661-001
.45999999+001	.57736729-002	-.54814304-002	.23107247-001	.57760611-002	.26396412-001	-.21140176-001
.47999999+001	.47401646-002	-.48755020-002	.23323353-001	-.30471682-002	.22281809-001	-.19996636-001
.49999999+001	.38284240-002	-.42400735-002	.22095182-001	-.87697286-002	.18473029-001	-.18122949-001
.51999999+001	.30437929-002	-.36095195-002	.19980440-001	-.12016784-001	.15052687-001	-.16046996-001
.54000000+001	.23824914-002	-.30105704-002	.17413191-001	-.13390837-001	.12061827-001	-.13855623-001
.56000000+001	.18361839-002	-.24620841-002	.14712836-001	-.13431071-001	.95084950-002	-.11691997-001
.57999999+001	.13935133-002	-.19755504-002	.12099148-001	-.12592462-001	.73743189-002	-.96577831-002
.59999999+001	.10414802-002	-.15560988-002	.97099708-002	-.11239112-001	.56323449-002	-.78161070-002
.61999999+001	.75655993-003	-.12037805-002	.76192338-002	-.96471537-002	.42337306-002	-.62076229-002
.63999999+001	.55573158-003	-.91492787-003	.58537325-002	-.80136073-002	.31331387-002	-.48381155-002
.65999999+001	.39679157-003	-.68343946-003	.44077768-002	-.64684807-002	.22828309-002	-.37028209-002
.67999999+001	.27902539-003	-.50189317-003	.32552673-002	-.50880965-002	.16375578-002	-.27940868-002
.69999999+001	.19322905-003	-.36243343-003	.23591094-002	-.39081920-002	.11564025-002	-.20571565-002
.71999999+001	.13175696-003	-.25742141-003	.16781155-002	-.29357973-002	.80376446-003	-.14941896-002
.74000000+001	.88432223-004	-.17936325-003	.11717072-002	-.21593015-002	.54867716-003	-.10670601-002
.75999999+001	.58390870-004	-.12364982-003	.80280845-003	-.15564515-002	.36954999-003	-.74939318-003
.77999999+001	.37893599-004	-.83649099-004	.53934566-003	-.11003012-002	.24419906-003	-.51765442-003
.79999999+001	.24130211-004	-.55693169-004	.35474865-003	-.76330937-003	.15820661-003	-.35175987-003
.82000000+001	.15034004-004	-.36497698-004	.22779087-003	-.51989634-003	.10021581-003	-.23517087-003
.84000000+001	.91163663-005	-.23544883-004	.14204377-003	-.34780774-003	.61736654-004	-.15470620-003
.86000000+001	.53264322-005	-.14953235-004	.85149323-004	-.22862276-003	.36611459-004	-.10015320-003
.88000000+001	.29367059-005	-.93591238-005	.49051292-004	-.14770212-003	.20465802-004	-.63811307-004
.90000000+001	.14530537-005	-.57567273-005	.24272905-004	-.93810706-004	.10253952-004	-.40017041-004
.92000000+001	.54603867-006	-.34901133-005	.92875054-005	-.58588587-004	.38963426-005	-.24702579-004
.94000000+001	.00000000	-.20837027-005	.00000000	-.35987609-004	.21694043-018	-.15011429-004

TABLE I CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	T27	T27'	T28	T28'
.00000000	.00000000	-.29658196-002	.00000000	-.93582014-002
.20000000+000	-.51779492-003	-.22112252-002	-.16327639-002	-.69657565-002
.39999999+000	-.88400450-003	-.14497805-002	-.27843693-002	-.45460471-002
.59999999+000	-.10975764-002	-.68678533-003	-.34506787-002	-.21202308-002
.79999999+000	-.11597596-002	.60247458-004	-.36362948-002	.24699474-003
.99999999+000	-.10763847-002	.76343519-003	-.33622460-002	.24581238-002
.12000000+001	-.85963292-003	.13878373-002	-.26711993-002	.43969019-002
.14000000+001	-.52899327-003	.18962085-002	-.16295403-002	.59454442-002
.16000000+001	-.11115884-003	.22547622-002	-.32583964-003	.70029059-002
.18000000+001	.36126514-003	.24391117-002	.11343628-002	.75031256-002
.20000000+001	.85216758-003	.24392798-002	.26369358-002	.74280816-002
.21999999+001	.13251509-002	.22626496-002	.40695568-002	.68142212-002
.24000000+001	.17470630-002	.19340429-002	.53325003-002	.57498657-002
.25999999+001	.20912341-002	.14927237-002	.63480038-002	.43637589-002
.28000000+001	.23398456-002	.98686205-003	.70666202-002	.28069102-002
.30000000+001	.24850328-002	.46653862-003	.74695747-002	.12315080-002
.32000000+001	.25285954-002	-.22520753-004	.75669783-002	-.22871568-003
.33999999+001	.24804855-002	-.44521326-003	.73925816-002	-.14729221-002
.36000000+001	.23564700-002	-.77896215-003	.69963573-002	-.24402679-002
.37999999+001	.21754595-002	-.10145699-002	.64364217-002	-.31095388-002
.39999999+001	.19570489-002	-.11543599-002	.57716562-002	-.34928913-002
.41999999+001	.17194051-002	-.12091224-002	.50559622-002	-.36262299-002
.43999999+001	.14780191-002	-.11946564-002	.43345565-002	-.35588147-002
.45999999+001	.12449788-002	-.11286245-002	.36422497-002	-.33440999-002
.47999999+001	.10288611-002	-.10281415-002	.30033325-002	-.30329070-002
.49999999+001	.83501106-003	-.90822717-003	.24325684-002	-.26691889-002
.51999999+001	.66604851-003	-.78103650-003	.19367966-002	-.22880654-002
.54000000+001	.52246761-003	-.65568278-003	.15167507-002	-.19155323-002
.56000000+001	.40322916-003	-.53844112-003	.11688197-002	-.15692221-002
.57999999+001	.30628963-003	-.43315741-003	.88659669-003	-.12597035-002
.59999999+001	.22903885-003	-.34173522-003	.66214413-003	-.99196012-003
.61999999+001	.16863944-003	-.26462057-003	.48696539-003	-.76683023-003
.63999999+001	.12227356-003	-.20124030-003	.35270224-003	-.58228802-003
.65999999+001	.87308349-004	-.15037315-003	.25159678-003	-.43451597-003
.67999999+001	.61394662-004	-.11044657-003	.17676115-003	-.31875467-003
.69999999+001	.42513720-004	-.79761219-004	.12229883-003	-.22993963-003
.71999999+001	.28985565-004	-.56649596-004	.83318109-004	-.16314703-003
.74000000+001	.19451618-004	-.39578374-004	.55873123-004	-.11387749-003
.75999999+001	.12841488-004	-.27205240-004	.36861721-004	-.78210122-004
.77999999+001	.83320511-005	-.18401265-004	.23902727-004	-.52858825-004
.79999999+001	.53046319-005	-.12249038-004	.15209249-004	-.35160657-004
.82000000+001	.33042374-005	-.80254104-005	.94689677-005	-.23021323-004
.84000000+001	.20031677-005	-.51759436-005	.57378729-005	-.14838203-004
.86000000+001	.11701183-005	-.32863211-005	.33503683-005	-.94156201-005
.88000000+001	.64499012-006	-.20543083-005	.18462083-005	-.58825865-005
.90000000+001	.31906388-006	-.12644153-005	.91312779-006	-.36184557-005
.92000000+001	.11987527-006	-.76632429-006	.34316070-006	-.21922322-005
.94000000+001	.13552527-019	-.45736349-006	.30339252-009	-.13077971-005

TABLE II.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	F1	F1'	F1''	T11	T11'
.00000000	.00000000	.00000000	.33205733+000	.00000000	.33205810+000
.20000000+000	.66409995-002	.66407790-001	.33198383+000	.66407819-001	.33198383+000
.39999999+000	.26559883-001	.13276415+000	.33146983+000	.13276418+000	.33146984+000
.59999999+000	.59734636-001	.19893724+000	.33007912+000	.19893727+000	.33007912+000
.79999999+000	.10610821+000	.26470913+000	.32738926+000	.26470916+000	.32738926+000
.99999999+000	.16557172+000	.32978002+000	.32300711+000	.32978005+000	.32300711+000
.12000000+001	.23794871+000	.39377609+000	.31658918+000	.39377612+000	.31658918+000
.14000000+001	.32298156+000	.45626175+000	.30786538+000	.45626178+000	.30786538+000
.16000000+001	.42032075+000	.51675677+000	.29666345+000	.51675680+000	.29666345+000
.18000000+001	.52951802+000	.57475813+000	.28293101+000	.57475816+000	.28293101+000
.20000000+001	.65002435+000	.62976572+000	.26675154+000	.62976575+000	.26675154+000
.21999999+001	.78119332+000	.68131036+000	.24835091+000	.68131039+000	.24835091+000
.24000000+001	.92229010+000	.72898192+000	.22809175+000	.72898195+000	.22809175+000
.25999999+001	.10725059+001	.77245500+000	.20645462+000	.77245504+000	.20645462+000
.28000000+001	.12309772+001	.81150961+000	.18400659+000	.81150964+000	.18400659+000
.30000000+001	.13968082+001	.84604443+000	.16136031+000	.84604446+000	.16136031+000
.32000000+001	.15690949+001	.87608144+000	.13912805+000	.87608147+000	.13912805+000
.33999999+001	.17469500+001	.90176120+000	.11787624+000	.90176124+000	.11787624+000
.36000000+001	.19295251+001	.92332965+000	.98086278-001	.92332968+000	.98086279-001
.37999999+001	.21160297+001	.94111798+000	.80125918-001	.94111801+000	.80125918-001
.39999999+001	.23057463+001	.95551821+000	.64234121-001	.95551825+000	.64234121-001
.41999999+001	.24980396+001	.96695706+000	.50519748-001	.96695709+000	.50519748-001
.43999999+001	.26923608+001	.97587081+000	.38972611-001	.97587085+000	.38972611-001
.45999999+001	.28882479+001	.98268348+000	.29483772-001	.98268352+000	.29483772-001
.47999999+001	.30853206+001	.98778951+000	.21871187-001	.98778954+000	.21871187-001
.49999999+001	.32832736+001	.99154188+000	.15906799-001	.99154192+000	.15906799-001
.51999999+001	.34818675+001	.99424552+000	.11341789-001	.99424555+000	.11341789-001
.54000000+001	.36809190+001	.99615529+000	.79276602-002	.99615532+000	.79276603-002
.56000000+001	.38802906+001	.99747775+000	.54319580-002	.99747779+000	.54319580-002
.57999999+001	.40798818+001	.99837548+000	.36484139-002	.99837551+000	.36484139-002
.59999999+001	.42796208+001	.99897286+000	.24020400-002	.99897289+000	.24020400-002
.61999999+001	.44794572+001	.99936252+000	.15501708-002	.99936255+000	.15501708-002
.63999999+001	.46793565+001	.99961168+000	.98061518-003	.99961172+000	.98061519-003
.65999999+001	.48792957+001	.99976785+000	.60804430-003	.99976789+000	.60804430-003
.67999999+001	.50792597+001	.99986380+000	.36956258-003	.99986384+000	.36956258-003
.69999999+001	.52792387+001	.99992159+000	.22016895-003	.99992162+000	.22016895-003
.71999999+001	.54792267+001	.99995570+000	.12856980-003	.99995574+000	.12856980-003
.74000000+001	.56792200+001	.99997544+000	.73592973-004	.99997548+000	.73592974-004
.75999999+001	.58792153+001	.99998664+000	.41290301-004	.99998667+000	.41290302-004
.77999999+001	.60792143+001	.99999286+000	.22707743-004	.99999290+000	.22707743-004
.79999999+001	.62792133+001	.99999626+000	.12240919-004	.99999629+000	.12240920-004
.82000000+001	.64792127+001	.99999807+000	.64679739-005	.99999811+000	.64679739-005
.84000000+001	.66792125+001	.99999902+000	.33499364-005	.99999906+000	.33499365-005
.86000000+001	.68792123+001	.99999951+000	.17006657-005	.99999954+000	.17006658-005
.88000000+001	.70792123+001	.99999975+000	.84628270-006	.99999979+000	.84628271-006
.90000000+001	.72792122+001	.99999987+000	.41278702-006	.99999991+000	.41278702-006
.92000000+001	.74792122+001	.99999993+000	.19735615-006	.99999997+000	.19735615-006
.94000000+001	.76792122+001	.99999996+000	.92488849-007	.99999999+000	.92488850-007

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	T12	T12'	G21	G21'	G21''
.00000000	.00000000	-.33058852+000	.00000000	.00000000	.45612710-001
.20000000+000	-.61703996-001	-.28642333+000	.90821392-003	.90446795-002	.44494532-001
.39999999+000	-.11455137+000	-.24199891+000	.35899488-002	.17672618-001	.41498735-001
.59999999+000	-.15848620+000	-.19732373+000	.79264612-002	.25540750-001	.36952051-001
.79999999+000	-.19348351+000	-.15269729+000	.13737021-001	.32372765-001	.31195706-001
.99999999+000	-.21960608+000	-.10869323+000	.20792560-001	.37962068-001	.24585150-001
.12000000+001	-.23705600+000	-.66122884-001	.28829872-001	.42174163-001	.17484579-001
.14000000+001	-.24621642+000	-.25973063-001	.37566146-001	.44947448-001	.10256654-001
.16000000+001	-.24767825+000	.10682324-001	.46713424-001	.46291538-001	.32482933-002
.18000000+001	-.24224687+000	.42792028-001	.55992422-001	.46282485-001	-.32259767-002
.20000000+001	-.23092366+000	.69447168-001	.65145055-001	.45054572-001	-.89010904-002
.21999999+001	-.21487596+000	.89994671-001	.73944990-001	.42788860-001	-.13576611-001
.24000000+001	-.19535643+000	.10412603+000	.82205623-001	.39699074-001	-.17127685-001
.25999999+001	-.17364859+000	.11192506+000	.89785057-001	.36015888-001	-.19509897-001
.28000000+001	-.15097779+000	.11386456+000	.96587991-001	.31970945-001	-.20756990-001
.30000000+001	-.12844012+000	.11075162+000	.10256389+000	.27782053-001	-.20971475-001
.32000000+001	-.10694457+000	.10363119+000	.10770397+000	.23640876-001	-.20309287-001
.33999999+001	-.87177304-001	.93665654-001	.11203396+000	.19704136-001	-.18960574-001
.36000000+001	-.69590602-001	.82011855-001	.11560714+000	.16088809-001	-.17129223-001
.37999999+001	-.54414988-001	.69715216-001	.11849609+000	.12871340-001	-.15013746-001
.39999999+001	-.41689585-001	.57634832-001	.12078484+000	.10090344-001	-.12791686-001
.41999999+001	-.31303816-001	.46405256-001	.12256179+000	.77519628-002	-.10608911-001
.43999999+001	-.23043202-001	.36432925-001	.12391389+000	.58368216-002	-.85742389-002
.45999999+001	-.16633015-001	.27919498-001	.12492227+000	.43075629-002	-.67589791-002
.47999999+001	-.11775423-001	.20901790-001	.12565944+000	.31160565-002	-.52003740-002
.49999999+001	-.81778650-002	.15298128-001	.12618770+000	.22096450-002	-.39075913-002
.51999999+001	-.55721877-002	.10953053-001	.12655881+000	.15360498-002	-.28689037-002
.54000000+001	-.37254816-002	.76751886-002	.12681440+000	.10468225-002	-.20588993-002
.56000000+001	-.24442362-002	.52658869-002	.12698698+000	.69942692-003	-.14448112-002
.57999999+001	-.15737195-002	.35384508-002	.12710123+000	.45817043-003	-.99169669-003
.59999999+001	-.99435715-003	.23293107-002	.12717539+000	.29426485-003	-.66595723-003
.61999999+001	-.61657518-003	.15023790-002	.12722258+000	.18530399-003	-.43763088-003
.63999999+001	-.37518716-003	.94957340-003	.12725204+000	.11441205-003	-.28147833-003
.65999999+001	-.22403256-003	.58818479-003	.12727006+000	.69263027-004	-.17722599-003
.67999999+001	-.13126629-003	.35707746-003	.12728087+000	.41112269-004	-.10924860-003
.69999999+001	-.75464655-004	.21246766-003	.12728723+000	.23926121-004	-.65942108-004
.71999999+001	-.42563954-004	.12391305-003	.12729090+000	.13651579-004	-.38977475-004
.74000000+001	-.23549859-004	.70834189-004	.12729297+000	.76359002-005	-.22563578-004
.75999999+001	-.12778653-004	.39689470-004	.12729412+000	.41862003-005	-.12793213-004
.77999999+001	-.67976328-005	.21798028-004	.12729474+000	.22485102-005	-.71048955-005
.79999999+001	-.35421842-005	.11734658-004	.12729508+000	.11823559-005	-.38651446-005
.82000000+001	-.18052935-005	.61920729-005	.12729525+000	.60769826-006	-.20597805-005
.84000000+001	-.89592738-006	.32026884-005	.12729534+000	.30426376-006	-.10753027-005
.86000000+001	-.43125896-006	.16237032-005	.12729538+000	.14730413-006	-.54990254-006
.88000000+001	-.19725663-006	.80688602-006	.12729540+000	.67769533-007	-.27545028-006
.90000000+001	-.81993270-007	.39303512-006	.12729541+000	.28296502-007	-.13511103-006
.92000000+001	-.26340065-007	.18765677-006	.12729541+000	.91163411-008	-.64358131-007
.94000000+001	.00000000	.87823523-007	.12729542+000	-.43368086-018	-.30426677-007

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	G22	G22'	G22''	G23	G23'	G23''
.00000000	.00000000	.00000000	.16790783+000	.00000000	.00000000	.91976521-001
.20000000+000	.31401371-002	.30330008-001	.13575817+000	.18314129-002	.18238863-001	.89729765-001
.39999999+000	.11718695-001	.54461193-001	.10593835+000	.72394318-002	.35640236-001	.83708560-001
.59999999+000	.24542902-001	.72867641-001	.78543376-001	.15985387-001	.51514200-001	.74566976-001
.79999999+000	.40517427-001	.86050205-001	.53723268-001	.27705893-001	.65304507-001	.62988503-001
.99999999+000	.58649931-001	.94537893-001	.31616695-001	.41940189-001	.76594607-001	.49685643-001
.12000000+001	.78056554-001	.98885870-001	.12343704-001	.58158600-001	.85112541-001	.35389199-001
.14000000+001	.97966660-001	.99670019-001	-.40113616-002	.75791701-001	.90732683-001	.20827567-001
.16000000+001	.11772616+000	.97478197-001	-.17415515-001	.94259357-001	.93472553-001	.66984852-002
.18000000+001	.13679878+000	.92898632-001	-.27899827-001	.11299852+000	.93483377-001	-.63644904-002
.20000000+001	.15476481+000	.86506199-001	-.35567670-001	.13148846+000	.91033793-001	-.17826360-001
.21999999+001	.17131694+000	.78847607-001	-.40597255-001	.14927207+000	.86486970-001	-.27281353-001
.24000000+001	.18625316+000	.70426709-001	-.43237703-001	.16597199+000	.80272360-001	-.34475230-001
.25999999+001	.19946680+000	.61691259-001	-.43798658-001	.18130077+000	.72854149-001	-.39315404-001
.28000000+001	.21093426+000	.53022325-001	-.42634237-001	.19506458+000	.64599103-001	-.41866725-001
.30000000+001	.22070083+000	.44727361-001	-.40122927-001	.20716070+000	.56246711-001	-.42332932-001
.32000000+001	.22886571+000	.37037510-001	-.36645612-001	.21756942+000	.47884293-001	-.41026052-001
.33999999+001	.23556676+000	.30109306-001	-.32564159-001	.22634174+000	.39929105-001	-.38327887-001
.36000000+001	.24096618+000	.24030385-001	-.28202877-001	.23358422+000	.32518506-001	-.34648827-001
.37999999+001	.24523749+000	.18828482-001	-.23834655-001	.23944267+000	.26108178-001	-.30389269-001
.39999999+001	.24855472+000	.14482624-001	-.19672828-001	.24408627+000	.20477433-001	-.25908028-001
.41999999+001	.25108384+000	.10935353-001	-.15868989-001	.24769330+000	.15739881-001	-.21500531-001
.43999999+001	.25297668+000	.81048472-002	-.12516132-001	.25043931+000	.11857402-001	-.17387736-001
.45999999+001	.25436722+000	.58959623-002	-.96559523-002	.25248833+000	.87552955-002	-.13714989-001
.47999999+001	.25536988+000	.42095307-002	-.72887878-002	.25398703+000	.63368425-002	-.10558787-001
.49999999+001	.25607945+000	.29495360-002	-.53846361-002	.25506157+000	.44959411-002	-.79387504-002
.51999999+001	.25657224+000	.20280928-002	-.38939001-002	.25581685+000	.31270577-002	-.58320494-002
.54000000+001	.25690810+000	.13683917-002	-.27568466-002	.25633731+000	.21322495-002	-.41879287-002
.56000000+001	.25713272+000	.90593558-003	-.19111739-002	.25668892+000	.14254227-002	-.29406100-002
.57999999+001	.25728012+000	.58847163-003	-.12974752-002	.25692182+000	.93425833-003	-.20195957-002
.59999999+001	.25737502+000	.37503631-003	-.86268691-003	.25707308+000	.60037085-003	-.13570334-002
.61999999+001	.25743498+000	.23448754-003	-.56182430-003	.25716940+000	.37827785-003	-.89229904-003
.63999999+001	.25747213+000	.14382831-003	-.35840487-003	.25722954+000	.23369426-003	-.57425622-003
.65999999+001	.25749472+000	.86541871-004	-.22397625-003	.25726636+000	.14155844-003	-.36178205-003
.67999999+001	.25750819+000	.51079045-004	-.13712282-003	.25728846+000	.84076791-004	-.22314945-003
.69999999+001	.25751608+000	.29571055-004	-.82246808-004	.25730147+000	.48962912-004	-.13477401-003
.71999999+001	.25752060+000	.16790438-004	-.48333599-004	.25730898+000	.27957647-004	-.79712492-004
.74000000+001	.25752315+000	.93491643-005	-.27830228-004	.25731323+000	.15651459-004	-.46174380-004
.75999999+001	.25752455+000	.51039272-005	-.15701333-004	.25731558+000	.85897701-005	-.26198352-004
.77999999+001	.25752531+000	.27307548-005	-.86800224-005	.25731687+000	.46203415-005	-.14551046-004
.79999999+001	.25752571+000	.14307632-005	-.47019668-005	.25731755+000	.24344252-005	-.79289655-005
.82000000+001	.25752592+000	.73294211-006	-.24958542-005	.25731791+000	.12549317-005	-.42309158-005
.84000000+001	.25752603+000	.36587598-006	-.12981978-005	.25731809+000	.63115889-006	-.22130827-005
.86000000+001	.25752608+000	.17666854-006	-.66166098-006	.25731818+000	.30769309-006	-.11355129-005
.88000000+001	.25752611+000	.81101293-007	-.33042569-006	.25731822+000	.14306838-006	-.57225490-006
.90000000+001	.25752612+000	.33806724-007	-.16165276-006	.25731824+000	.60687284-007	-.28403421-006
.92000000+001	.25752612+000	.10880267-007	-.77445435-007	.25731825+000	.19496318-007	-.13963737-006
.94000000+001	.25752612+000	.00000000	-.36301891-007	.25731825+000	-.17347234-017	-.68796928-007

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	F21	F21'	F21''	F22	F22'	F22''
.00000000	.00000000	.00000000	.49809172+000	.00000000	.00000000	.64824216-001
.20000000+000	.99613528-002	.99606525-001	.49785966+000	.12963475-002	.12961516-001	.64759471-001
.39999999+000	.39832614-001	.19905431+000	.49628505+000	.51818471-002	.25879258-001	.64327058-001
.59999999+000	.89546456-001	.29794419+000	.49206720+000	.11638031-001	.38644420-001	.63176643-001
.79999999+000	.15893002+000	.39562219+000	.48396863+000	.20617791-001	.51080150-001	.60981308-001
.99999999+000	.24765569+000	.49119875+000	.47088407+000	.32032371-001	.62948396-001	.57460260-001
.12000000+001	.35519709+000	.58358377+000	.45192962+000	.45740237-001	.73961866-001	.52406886-001
.14000000+001	.48079417+000	.67154078+000	.42654183+000	.61538906-001	.83801861-001	.45718570-001
.16000000+001	.62343089+000	.75376064+000	.39457251+000	.79160937-001	.92141834-001	.37423352-001
.18000000+001	.78182963+000	.82895251+000	.35636163+000	.98275108-001	.98675498-001	.27697691-001
.20000000+001	.95446481+000	.89594545+000	.31276987+000	.11849349+000	.10314711+000	.16869739-001
.21999999+001	.11395973+001	.95379139+000	.26515599+000	.13938451+000	.10538064+000	.54040126-002
.24000000+001	.13353285+001	.10018571+001	.21529089+000	.16049145+000	.10530380+000	-.61338606-002
.25999999+001	.15396706+001	.10398933+001	.16521178+000	.18135485+000	.10296326+000	-.17129879-001
.28000000+001	.17506275+001	.10680687+001	.11703129+000	.20153686+000	.98528067-001	-.26985535-001
.30000000+001	.19662786+001	.10869650+001	.72727683-001	.22064500+000	.92279888-001	-.35183416-001
.32000000+001	.21848574+001	.10975292+001	.33947552-001	.23835263+000	.84590926-001	-.41343969-001
.33999999+001	.24048164+001	.11009910+001	.18522587-002	.25441400+000	.75892106-001	-.45263967-001
.36000000+001	.26248739+001	.10987563+001	-.22968910-001	.26867235+000	.66635971-001	-.46930604-001
.37999999+001	.26440370+001	.10922901+001	-.40508304-001	.28106047+000	.57259354-001	-.46509831-001
.39999999+001	.30616024+001	.10830053+001	-.51276445-001	.29159412+000	.48150697-001	-.44312445-001
.41999999+001	.32771363+001	.10721709+001	-.56182473-001	.30035985+000	.39625788-001	-.40745260-001
.43999999+001	.34904386+001	.10608462+001	-.56383399-001	.30749884+000	.31914003-001	-.36256559-001
.45999999+001	.37014971+001	.10498477+001	-.53128906-001	.31318918+000	.25155251-001	-.31284813-001
.47999999+001	.39104379+001	.10397443+001	-.47624729-001	.31762842+000	.19406263-001	-.26217631-001
.49999999+001	.41174776+001	.10308767+001	-.40930097-001	.32101823+000	.14653700-001	-.21364883-001
.51999999+001	.43228813+001	.10233944+001	-.33895886-001	.32355197+000	.10831133-001	-.16946788-001
.54000000+001	.45269281+001	.10172992+001	-.27142041-001	.32540595+000	.78370460-002	-.13095163-001
.56000000+001	.47298870+001	.10124919+001	-.21067038-001	.32673404+000	.55515431-002	-.98643745-002
.57999999+001	.49320001+001	.10088129+001	-.15879208-001	.32766550+000	.38502437-002	-.72479604-002
.59999999+001	.51334750+001	.10060767+001	-.11639392-001	.32830515+000	.26145973-002	-.51971485-002
.61999999+001	.53344812+001	.10040966+001	-.83059149-002	.32873528+000	.17385622-002	-.36383345-002
.63999999+001	.55351526+001	.10027008+001	-.57754216-002	.32901851+000	.11320571-002	-.24876445-002
.65999999+001	.57355906+001	.10017417+001	-.39158903-002	.32920115+000	.72186994-003	-.16617330-002
.67999999+001	.59358703+001	.10010988+001	-.25905065-002	.32931650+000	.45079199-003	-.10947828-002
.69999999+001	.61360449+001	.10006783+001	-.16728629-002	.32938784+000	.27569273-003	-.69221266-003
.71999999+001	.63361517+001	.10004098+001	-.10549650-002	.32943106+000	.16511891-003	-.43186223-003
.74000000+001	.65362156+001	.10002422+001	-.64993735-003	.32945669+000	.96840022-004	-.26347712-003
.75999999+001	.67362530+001	.10001401+001	-.39128440-003	.32947158+000	.55605128-004	-.15721950-003
.77999999+001	.69362744+001	.10000792+001	-.23025830-003	.32948005+000	.31246248-004	-.91770190-004
.79999999+001	.71362863+001	.10000438+001	-.13247660-003	.32948476+000	.17168732-004	-.52406788-004
.82000000+001	.73362929+001	.10000236+001	-.74533476-004	.32948732+000	.92084774-005	-.29283116-004
.84000000+001	.75362964+001	.10000123+001	-.41013680-004	.32948868+000	.48038353-005	-.16011750-004
.86000000+001	.77362982+001	.10000062+001	-.22076970-004	.32948938+000	.24186477-005	-.85683179-005
.88000000+001	.79362991+001	.10000030+001	-.11626376-004	.32948972+000	.11544816-005	-.44877338-005
.90000000+001	.81362995+001	.10000013+001	-.59909794-005	.32948988+000	.49864887-006	-.23007499-005
.92000000+001	.83362997+001	.10000004+001	-.30209868-005	.32948994+000	.16558774-006	-.11546637-005
.94000000+001	.85362997+001	.10000000+001	-.14908762-005	.32948996+000	-.21684043-018	-.56730377-006

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	F23	F23'	F23''	F24	F24'	F24''
.00000000	.00000000	.00000000	.46962223-002	.00000000	.00000000	.11139946-001
.20000000+000	.93911948-004	.93894093-003	.46903270-002	.22275982-003	.22270451-002	.11121761-001
.39999999+000	.37532604-003	.18739137-002	.46512280-002	.89006138-003	.44421472-002	.11005732-001
.59999999+000	.84257526-003	.27951559-002	.45481030-002	.19969939-002	.66173909-002	.10711082-001
.79999999+000	.14914429-002	.36870489-002	.43535850-002	.35315598-002	.87104053-002	.10174507-001
.99999999+000	.23140763-002	.45290439-002	.40461605-002	.54721538-002	.10668175-001	.93534788-002
.12000000+001	.32981342-002	.52970885-002	.36127292-002	.77858736-002	.12431560-001	.82298235-002
.14000000+001	.44262713-002	.59655492-002	.30509172-002	.10427803-001	.13940470-001	.68125974-002
.16000000+001	.56760482-002	.65095309-002	.23706661-002	.13341378-001	.15139465-001	.51392691-002
.18000000+001	.70203304-002	.69074043-002	.15946355-002	.16459881-001	.15983355-001	.32743625-002
.20000000+001	.84231915-002	.71432633-002	.75707369-003	.19709008-001	.16442216-001	.13050434-002
.21999999+001	.98662732-002	.72089925-002	-.98954886-004	.23010330-001	.16505223-001	-.66435288-003
.24000000+001	.11300494-001	.71056293-002	-.92578805-003	.26285350-001	.16182722-001	-.25322446-002
.25999999+001	.12697939-001	.68437782-002	-.16763124-002	.29459773-001	.15506174-001	-.41909804-002
.28000000+001	.14028725-001	.64429661-002	-.23092713-002	.32467535-001	.14525858-001	-.55576754-002
.30000000+001	.15267636-001	.59299914-002	-.27938707-002	.35254167-001	.13306598-001	-.65730242-002
.32000000+001	.16395348-001	.53364883-002	-.31129186-002	.37779149-001	.11922034-001	-.72086954-002
.33999999+001	.17399105-001	.46960530-002	-.32640060-002	.40017040-001	.10448242-001	-.74685218-002
.36000000+001	.18272825-001	.40413424-002	-.32586291-002	.41957338-001	.89575341-002	-.73854886-002
.37999999+001	.19016647-001	.34015319-002	-.31195461-002	.43603175-001	.75132233-002	-.70152890-002
.39999999+001	.19636033-001	.28004309-002	-.28769664-002	.44969127-001	.61559184-002	-.64277611-002
.41999999+001	.20140574-001	.22554150-002	-.25643146-002	.46078442-001	.49516083-002	-.56977772-002
.43999999+001	.20542665-001	.17771892-002	-.22142807-002	.46960081-001	.38915064-002	-.48969801-002
.45999999+001	.20856214-001	.13702594-002	-.18558945-002	.47645867-001	.29933880-002	-.40874465-002
.47999999+001	.21095485-001	.10339345-002	-.15115177-002	.48168020-001	.22538361-002	-.33177810-002
.49999999+001	.21274192-001	.76359414-003	-.11979917-002	.48557214-001	.16613201-002	-.26216623-002
.51999999+001	.21404844-001	.55203718-003	-.92478365-003	.48841230-001	.11989495-002	-.20184551-002
.54000000+001	.21498357-001	.39071910-003	-.69585001-003	.49044172-001	.84724847-003	-.15152766-002
.56000000+001	.21563889-001	.27077117-003	-.51070434-003	.49186177-001	.58630321-003	-.11098458-002
.57999999+001	.21608858-001	.18375050-003	-.36580305-003	.49283490-001	.39736181-003	-.79352150-003
.59999999+001	.21639079-001	.12211960-003	-.25583409-003	.49348806-001	.26377110-003	-.55408246-003
.61999999+001	.21658970-001	.79489662-004	-.17477624-003	.49391748-001	.17150674-003	-.37798691-003
.63999999+001	.21671794-001	.50630035-004	-.11667392-003	.49419403-001	.10923848-003	-.25200540-003
.65999999+001	.21679892-001	.31651265-004	-.76131798-004	.49436851-001	.68160559-004	-.16424734-003
.67999999+001	.21684902-001	.19353917-004	-.48570772-004	.49447635-001	.41664850-004	-.10467685-003
.69999999+001	.21687938-001	.11605233-004	-.30304090-004	.49454166-001	.24951290-004	-.65247112-004
.71999999+001	.21689741-001	.68134816-005	-.18494081-004	.49458040-001	.14538476-004	-.39784420-004
.74000000+001	.21690789-001	.39184092-005	-.11041973-004	.49460292-001	.84129205-005	-.23734420-004
.75999999+001	.21691386-001	.22059928-005	-.64507604-005	.49461574-001	.47355323-005	-.13855501-004
.77999999+001	.21691720-001	.12159658-005	-.36879541-005	.49462289-001	.26097334-005	-.79159097-005
.79999999+001	.21691902-001	.65644727-006	-.20635918-005	.49462679-001	.14069714-005	-.44265456-005
.82000000+001	.21691999-001	.34582335-006	-.11302467-005	.49462887-001	.74084013-006	-.24230354-005
.84000000+001	.21692049-001	.17731296-006	-.60600534-006	.49462995-001	.37967527-006	-.12964517-005
.86000000+001	.21692075-001	.87816538-007	-.31810576-006	.49463050-001	.18796977-006	-.68123908-006
.88000000+001	.21692087-001	.41278496-007	-.16349065-006	.49463076-001	.88318686-007	-.34095632-006
.90000000+001	.21692093-001	.17582953-007	-.82275737-007	.49463088-001	.37507382-007	-.17603479-006
.92000000+001	.21692095-001	.57685699-008	-.40544908-007	.49463093-001	.12334912-007	-.86712278-007
.94000000+001	.21692096-001	.00000000	-.19566459-007	.49463094-001	.00000000	-.41829704-007

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	T21	T21'	T22	T22'	T23	T23'
.00000000	.00000000	.16595524+000	.00000000	.64793639-001	.00000000	.46936846-002
.20000000+000	.33182843-001	.16579631+000	.12955376-001	.64728750-001	.93843164-003	.46877790-002
.39999999+000	.66258375-001	.16473583+000	.25866978-001	.64296388-001	.18728952-002	.46486843-002
.59999999+000	.98959315-001	.16190910+000	.38625019-001	.63146126-001	.27936297-002	.45455723-002
.79999999+000	.13084971+000	.15650126+000	.51055676-001	.60951126-001	.36850191-002	.43510830-002
.99999999+000	.16133990+000	.14780049+000	.62917941-001	.57430704-001	.45265186-002	.40437128-002
.12000000+001	.18971381+000	.13526670+000	.73925597-001	.52378385-001	.52940822-002	.36103737-002
.14000000+001	.21517081+000	.11860695+000	.83760045-001	.45691711-001	.59620851-002	.30487057-002
.16000000+001	.23688234+000	.97845737-001	.92094872-001	.37398885-001	.65056444-002	.23666643-002
.18000000+001	.25406098+000	.73375728-001	.98623955-001	.27676498-001	.69031447-002	.15929199-002
.20000000+001	.26603640+000	.45974328-001	.10309174+000	.16852777-001	.71396960-002	.75572571-003
.21999999+001	.27233019+000	.16774352-001	.10532238+000	.53922150-002	.72041990-002	-.99858013-004
.24000000+001	.27271978+000	-.12816272-001	.10524376+000	-.61397029-002	.71007050-002	-.92618370-003
.25999999+001	.26728141+000	-.41241575-001	.10290270+000	-.17129244-001	.68388289-002	-.16761631-002
.28000000+001	.25640423+000	-.66956946-001	.98468292-001	-.26978275-001	.64381018-002	-.23085731-002
.30000000+001	.24077102+000	-.88597928-001	.92222207-001	-.35169827-001	.59253192-002	-.27926576-002
.32000000+001	.22130657+000	-.10513130+000	.84536538-001	-.41324790-001	.53321046-002	-.31112607-002
.33999999+001	.19909971+000	-.11596316+000	.75842021-001	-.45240325-001	.46920372-002	-.32620037-002
.36000000+001	.17530962+000	-.12096632+000	.66590946-001	-.46903895-001	.40377516-002	-.32564019-002
.37999999+001	.15106929+000	-.12056120+000	.57219851-001	-.46481567-001	.33983986-002	-.31172194-002
.39999999+001	.12739900+000	-.11543718+000	.48116879-001	-.44284094-001	.27977629-002	-.28746586-002
.41999999+001	.10514012+000	-.10663181+000	.39597540-001	-.40718109-001	.22531980-002	-.25621265-002
.43999999+001	.84915279-001	-.95291214-001	.31890979-001	-.36231612-001	.17753904-002	-.22122882-002
.45999999+001	.67116397-001	-.82555265-001	.25136937-001	-.31262744-001	.13688362-002	-.18539462-002
.47999999+001	.51917569-001	-.69446808-001	.19392043-001	-.26198785-001	.10328345-002	-.15100356-002
.49999999+001	.39306626-001	-.56796264-001	.14642920-001	-.21349313-001	.76276379-003	-.11967755-002
.51999999+001	.29127917-001	-.45205097-001	.10823153-001	-.16934323-001	.55142484-003	-.92381575-003
.54000000+001	.21128764-001	-.35044352-001	.78312741-002	-.13085477-001	.39027791-003	-.69510199-003
.56000000+001	.15003394-001	-.26479830-001	.55474638-002	-.98570618-002	.27046030-003	-.51014229-003
.57999999+001	.10430025-001	-.19513527-001	.38474256-002	-.72425895-002	.18353637-003	-.36539203-003
.59999999+001	.70988873-002	-.14031340-001	.26126939-002	-.51933078-002	.12197533-003	-.25554130-003
.61999999+001	.47307622-002	-.98490445-002	.17373049-002	-.36356582-002	.79394567-004	-.17457292-003
.63999999+001	.30869675-002	-.67512469-002	.11312446-002	-.24858261-002	.50618688-004	-.11653619-003
.65999999+001	.19724840-002	-.45207555-002	.72135627-003	-.16605275-002	.31612520-004	-.76046706-004
.67999999+001	.12342132-002	-.29580094-002	.45047419-003	-.10840028-002	.19339949-004	-.48511994-004
.69999999+001	.75625485-003	-.18917287-002	.27550029-003	-.69171966-003	.11590702-004	-.30267025-004
.71999999+001	.45377290-003	-.11827293-002	.16500485-003	-.43155783-003	.68048375-005	-.18471241-004
.74000000+001	.26660366-003	-.72304372-003	.96773853-004	-.26329344-003	.39133554-005	-.11028215-004
.75999999+001	.15334390-003	-.43228735-003	.55567557-004	-.15711115-003	.22040793-005	-.64426577-005
.77999999+001	.86309935-004	-.25290011-003	.31225376-004	-.91707687-004	.12153002-005	-.36832872-005
.79999999+001	.47498772-004	-.14462381-003	.17157395-004	-.52371527-004	.65549323-006	-.20609624-005
.82000000+001	.25514166-004	-.80949683-004	.92024668-005	-.29263656-004	.34526625-006	-.11267974-005
.84000000+001	.13328950-004	-.44335637-004	.48007354-005	-.16001242-004	.17697254-006	-.60522366-006
.86000000+001	.67197698-005	-.23762833-004	.24171043-005	-.85627561-005	.87591848-007	-.31769318-006
.88000000+001	.32114045-005	-.12454999-004	.11537527-005	-.44848630-005	.41114308-007	-.16327751-006
.90000000+001	.13885839-005	-.63999861-005	.49833707-006	-.22992969-005	.17449724-007	-.82167961-007
.92000000+001	.46153890-006	-.32154187-005	.16548508-006	-.11539438-005	.56508490-008	-.40491557-007
.94000000+001	.43368086-018	-.15824309-005	-.43368086-018	-.56695463-006	-.11011559-009	-.19540603-007

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	T24	T24'	T25	T25'	T26	T26'
.00000000	.00000000	.11133513-001	.00000000	-.82580426+000	.00000000	-.64257244-001
.20000000+000	.22257542-002	.11115302-001	-.15191612+000	-.69324508+000	-.11126689-001	-.45966849-001
.39999999+000	.44395654-002	.10999285-001	-.27723103+000	-.55972590+000	-.18781973-001	-.29534984-001
.59999999+000	.66135227-002	.10704669-001	-.37575750+000	-.42551527+000	-.22934594-001	-.12001463-001
.79999999+000	.87052612-002	.10158171-001	-.44749279+000	-.29217906+000	-.23602466-001	.52248112-002
.99999999+000	.10661777-001	.93472885-002	-.49286908+000	-.16247426+000	-.20907813-001	.21497484-001
.12000000+001	.12423947-001	.82238814-002	-.51297137+000	-.40122182-001	-.15122758-001	.35977932-001
.14000000+001	.13931704-001	.68070420-002	-.50969549+000	.70564541-001	-.66980711-002	.47736599-001
.16000000+001	.15129641-001	.51342732-002	-.48581731+000	.16519305+000	.37322253-002	.55899298-001
.18000000+001	.15972604-001	.32701235-002	-.44494954+000	.23989117+000	.15375523-001	.59779894-001
.20000000+001	.16430710-001	.13017667-002	-.39137640+000	.29191136+000	.27335341-001	.59043043-001
.21999999+001	.16493174-001	-.66847791-003	-.32977635+000	.32012612+000	.38590926-001	.53795201-001
.24000000+001	.16170377-001	-.25330709-002	-.26486592+000	.32530548+000	.48590529-001	.44618355-001
.25999999+001	.15493600-001	-.41904285-002	-.20101663+000	.31010054+000	.56342663-001	.32517243-001
.28000000+001	.14513733-001	-.55557524-002	-.14190635+000	.27871889+000	.61488581-001	.18786813-001
.30000000+001	.13294986-001	-.65698312-002	-.90262158-001	.23634969+000	.63842218-001	.48252697-002
.32000000+001	.11911173-001	-.72044222-002	-.47733736-001	.18845648+000	.63490584-001	-.80673082-002
.33999999+001	.10438323-001	-.74634283-002	-.14909275-001	.14008392+000	.60756066-001	-.18861498-001
.36000000+001	.89486904-002	-.73798768-002	.85428000-002	.95311639-001	.56130082-001	-.26908403-001
.37999999+001	.75055277-002	-.70094692-002	.23645153-001	.56939905-001	.50192485-001	-.31971285-001
.39999999+001	.61593828-002	-.64220250-002	.31845432-001	.26427632-001	.43532188-001	-.34184138-001
.41999999+001	.49461909-002	-.56923665-002	.34760119-001	.40435019-002	.36681761-001	-.33958415-001
.43999999+001	.38871231-002	-.48920749-002	.33963731-001	-.10846035-001	.30073340-001	-.31866608-001
.45999999+001	.29899052-002	-.40831586-002	.30842091-001	-.19437805-001	.24018825-001	-.28529705-001
.47999999+001	.22511647-002	-.33141579-002	.26512270-001	-.23174210-001	.18705575-001	-.24527622-001
.49999999+001	.16593071-002	-.26186973-002	.21799871-001	-.23492684-001	.14218964-001	-.20341439-001
.51999999+001	.11974673-002	-.20151012-002	.17258008-001	-.21660245-001	.10557252-001	-.16327196-001
.54000000+001	.84618158-003	-.15134612-002	.13211063-001	-.18689127-001	.76610290-002	-.12715098-001
.56000000+001	.58555786-003	-.11084843-002	.98085510-002	-.15316604-001	.54351873-002	-.96255156-002
.57999999+001	.39684560-003	-.79252742-003	.70783879-002	-.12027651-001	.37735281-002	-.70933800-002
.59999999+001	.26342375-003	-.55337531-003	.49730288-002	-.91004994-002	.25532129-002	-.50944092-002
.61999999+001	.17127808-003	-.37749646-003	.34055419-002	-.66596128-002	.17041704-002	-.35568128-002
.63999999+001	.10909118-003	-.25157354-003	.22752396-002	-.47258606-002	.11092113-002	-.24402718-002
.65999999+001	.68067692-004	-.16402815-003	.14840507-002	-.32583356-002	.70488690-003	-.16295555-002
.67999999+001	.41607541-004	-.10453548-003	.94555277-003	-.21858330-002	.44112492-003	-.10631652-002
.69999999+001	.24916669-004	-.65158031-004	.58872994-003	-.14283042-002	.25957128-003	-.67792387-003
.71999999+001	.14617998-004	-.39729564-004	.35831645-003	-.90986984-003	.16132022-003	-.42260066-003
.74000000+001	.84010648-005	-.23701398-004	.21321149-003	-.56544059-003	.94532198-004	-.25760149-003
.75999999+001	.47238126-005	-.13836064-004	.12403662-003	-.34299260-003	.54233426-004	-.15357470-003
.77999999+001	.26050065-005	-.79047201-005	.70530158-004	-.20317447-003	.30449181-004	-.89560427-004
.79999999+001	.14049502-005	-.44202442-005	.39171756-004	-.11757217-003	.17153098-004	-.51097596-004
.82000000+001	.73976998-006	-.24195636-005	.21214630-004	-.66485952-004	.89542533-005	-.28525119-004
.84000000+001	.37912404-006	-.12965800-005	.11164222-004	-.36750562-004	.46594155-005	-.15562832-004
.86000000+001	.18768663-006	-.68025150-006	.56649539-005	-.19861375-004	.23499347-005	-.83310779-005
.88000000+001	.88189339-007	-.34944632-006	.27225901-005	-.10496755-004	.11204279-005	-.43594484-005
.90000000+001	.37552605-007	-.17577697-006	.11828707-005	-.54259969-005	.53535391-006	-.22329221-005
.92000000+001	.12316726-007	-.86584694-007	.39471108-006	-.27437953-005	.15494532-006	-.11195931-005
.94000000+001	.00000000	-.41767389-007	.34694469-017	-.13574784-005	-.21522043-018	-.54956831-006

TABLE II CON'T.- BOUNDARY LAYER SOLUTIONS WITH HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	T27	T27'	T28	T28'
.00000000	.00000000	-.46479536-002	.00000000	-.11019395-001
.20000000+000	-.80458672-003	-.33958119-002	-.19071660-002	-.80457648-002
.39999999+000	-.13571327-002	-.21266748-002	-.32147121-002	-.50209463-002
.59999999+000	-.16545939-002	-.84843966-003	-.39136435-002	-.19698799-002
.79999999+000	-.16980548-002	.40588239-003	-.40069919-002	.10145717-002
.99999999+000	-.14974309-002	.15818691-002	-.35217739-002	.37886939-002
.12000000+001	-.10751140-002	.26106111-002	-.25170125-002	.61903259-002
.14000000+001	-.46790665-003	.34188270-002	-.10867599-002	.80162047-002
.16000000+001	.27331378-003	.39412055-002	.64264948-003	.91517226-002
.18000000+001	.10864707-002	.41330765-002	.25211871-002	.94987457-002
.20000000+001	.19035229-002	.39808849-002	.43886473-002	.90461798-002
.21999999+001	.26573575-002	.35079150-002	.60911332-002	.78684140-002
.24000000+001	.32891938-002	.27734812-002	.74977596-002	.61188084-002
.25999999+001	.37551294-002	.18652460-002	.85145617-002	.40086513-002
.28000000+001	.40305550-002	.88606830-003	.90930498-002	.17758945-002
.30000000+001	.41116836-002	-.61749020-004	.92319447-002	-.35171004-003
.32000000+001	.40138116-002	-.89128331-003	.89720987-002	-.21851719-002
.33999999+001	.37671793-002	-.15417513-002	.83860312-002	-.35987188-002
.36000000+001	.34111039-002	-.19833449-002	.75644872-002	-.45363515-002
.37999999+001	.29878263-002	-.22159695-002	.66027294-002	-.50071080-002
.39999999+001	.25371089-002	-.22632076-002	.55888854-002	-.50702705-002
.41999999+001	.20923400-002	-.21636931-002	.45958250-002	-.48157302-002
.43999999+001	.16784281-002	-.19621770-002	.36770347-002	-.43443820-002
.45999999+001	.13113520-002	-.17020428-002	.28660947-002	-.37521560-002
.47999999+001	.99903562-003	-.14202144-002	.21788220-002	-.31194804-002
.49999999+001	.74284020-003	-.11446054-002	.16169551-002	-.25063041-002
.51999999+001	.53952871-003	-.89369855-003	.11723569-002	-.19516599-002
.54000000+001	.38302584-003	-.67757911-003	.83097713-003	-.14762486-002
.56000000+001	.26593562-003	-.49972772-003	.57612243-003	-.10865368-002
.57999999+001	.18065398-003	-.35901218-003	.39085942-003	-.77917713-003
.59999999+001	.12011375-003	-.25150836-003	.25956804-003	-.54494358-003
.61999999+001	.78166324-004	-.17195938-003	.16877919-003	-.37207926-003
.63999999+001	.49836997-004	-.11481483-003	.10747540-003	-.24812182-003
.65999999+001	.31111588-004	-.74909479-004	.67032446-004	-.16169083-003
.67999999+001	.19023553-004	-.47771943-004	.40953509-004	-.10300677-003
.69999999+001	.11394421-004	-.29789429-004	.24510572-004	-.64171200-004
.71999999+001	.66853931-005	-.18168472-004	.14370700-004	-.39103645-004
.74000000+001	.38421729-005	-.10840144-004	.82535675-005	-.23312352-004
.75999999+001	.21625802-005	-.63283441-005	.46427371-005	-.13593439-004
.77999999+001	.11916599-005	-.36153434-005	.25569091-005	-.77639880-005
.79999999+001	.64235863-006	-.20214837-005	.13776194-005	-.43384214-005
.82000000+001	.33817336-006	-.11063732-005	.72496450-006	-.23730604-005
.84000000+001	.17327641-006	-.59277146-006	.37136454-006	-.12707425-005
.86000000+001	.85762912-007	-.31093230-006	.18380234-006	-.66621589-006
.88000000+001	.40289030-007	-.15968787-006	.86389098-007	-.34199060-006
.90000000+001	.17152063-007	-.80303924-007	.38948455-007	-.17190360-006
.92000000+001	.56244911-008	-.39544721-007	.12176437-007	-.84615378-007
.94000000+001	-.13552527-019	-.19070094-007	.14346705-009	-.40789384-007

TABLE III.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	$\tilde{F}_1$	$\tilde{F}_1'$	$\tilde{F}_1''$	$\tilde{T}_{11}$	$\tilde{T}_{11}'$
.00000000	.00000000	.00000000	.33205733+000	.84412969+000	.00000000
.20000000+000	.66409995-002	.66407790-001	.33198383+000	.84095448+000	-.31747313-001
.39999999+000	.26559883-001	.13276415+000	.33146983+000	.83143753+000	-.63387493-001
.59999999+000	.59734636-001	.19893724+000	.33007912+000	.81562400+000	-.94654429-001
.79999999+000	.10610821+000	.26470913+000	.32738926+000	.79362916+000	-.12511537+000
.99999999+000	.16557172+000	.32978002+000	.32300711+000	.76567016+000	-.15418773+000
.12000000+001	.23794871+000	.39377609+000	.31658918+000	.73209327+000	-.18116957+000
.14000000+001	.32296156+000	.45626175+000	.30786538+000	.69339334+000	-.20528595+000
.16000000+001	.42032075+000	.51675677+000	.29666345+000	.65022251+000	-.22575018+000
.18000000+001	.52951802+000	.57475813+000	.28293101+000	.60338545+000	-.24183638+000
.20000000+001	.65002435+000	.62976572+000	.26675154+000	.55381954+000	-.25295586+000
.21999999+001	.78119332+000	.68131036+000	.24835091+000	.50256023+000	-.25872731+000
.24000000+001	.92229010+000	.72898192+000	.22809175+000	.45069345+000	-.25903006+000
.25999999+001	.10725059+001	.77245500+000	.20645462+000	.39930231+000	-.25403084+000
.28000000+001	.12309772+001	.81150961+000	.18400659+000	.34940560+000	-.24417845+000
.30000000+001	.13968082+001	.84604443+000	.16136031+000	.30190866+000	-.23016613+000
.32000000+001	.15690949+001	.87608144+000	.13912805+000	.25755847+000	-.21286739+000
.33999999+001	.17469500+001	.90176120+000	.11787624+000	.21691594+000	-.19325553+000
.36000000+001	.19295251+001	.92332965+000	.98086278-001	.18034440+000	-.17231935+000
.37999999+001	.21160297+001	.94111798+000	.80125918-001	.14801433+000	-.15098707+000
.39999999+001	.23057463+001	.95551821+000	.64234121-001	.11992172+000	-.13006717+000
.41999999+001	.24980396+001	.96695706+000	.50519748-001	.95916163-001	-.11021083+000
.43999999+001	.26923608+001	.97587081+000	.38972611-001	.75734218-001	-.91896250-001
.45999999+001	.28882479+001	.98268348+000	.29483772-001	.59033986-001	-.75431655-001
.47999999+001	.30853206+001	.98778951+000	.21871187-001	.45427592-001	-.60972222-001
.49999999+001	.32832736+001	.99154188+000	.15906799-001	.34509373-001	-.48545323-001
.51999999+001	.34818675+001	.99424552+000	.11341789-001	.25878576-001	-.38079375-001
.54000000+001	.36809190+001	.99615529+000	.79276602-002	.19156251-001	-.29432533-001
.56000000+001	.38802906+001	.99747775+000	.54319580-002	.13996645-001	-.22418727-001
.57999999+001	.40798818+001	.99837548+000	.36484139-002	.10093768-001	-.16829653-001
.59999999+001	.42796203+001	.99897286+000	.24020400-002	.71840305-002	-.12452154-001
.61999999+001	.44794572+001	.99936252+000	.15501708-002	.50458530-002	-.90810255-002
.63999999+001	.46793565+001	.99961168+000	.98061518-003	.34971523-002	-.65276464-002
.65999999+001	.48792957+001	.99976785+000	.60804429-003	.23914627-002	-.46250450-002
.67999999+001	.50792597+001	.99986380+000	.36956258-003	.16133436-002	-.32301056-002
.69999999+001	.52792387+001	.99992159+000	.22016895-003	.10735734-002	-.22236225-002
.71999999+001	.54792267+001	.99995570+000	.12856980-003	.70449105-003	-.15088644-002
.74000000+001	.56792200+001	.99997544+000	.73592973-004	.45572538-003	-.10092177-002
.75999999+001	.58792163+001	.99998664+000	.41290301-004	.29044905-003	-.66537323-003
.77999999+001	.60792143+001	.99999286+000	.22707743-004	.18220994-003	-.43240607-003
.79999999+001	.62792133+001	.99999626+000	.12240919-004	.11233664-003	-.27699016-003
.82000000+001	.64792127+001	.99999807+000	.64679739-005	.67874362-004	-.17489726-003
.84000000+001	.66792125+001	.99999902+000	.33499364-005	.39985812-004	-.10885496-003
.86000000+001	.68792123+001	.99999951+000	.17006657-005	.22742780-004	-.66781911-004
.88000000+001	.70792123+001	.99999975+000	.84628270-006	.12233937-004	-.40384619-004
.90000000+001	.72792122+001	.99999987+000	.41278702-006	.59207343-005	-.24072395-004
.92000000+001	.74792122+001	.99999993+000	.19735615-006	.21822278-005	-.14143885-004
.94000000+001	.76792122+001	.99999996+000	.92488849-007	.00000000	-.81915182-005

TABLE III CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	$\tilde{G}_{21}$	$\tilde{G}_{21}'$	$\tilde{G}_{21}''$	$\tilde{G}_{22}$	$\tilde{G}_{22}'$	$\tilde{G}_{22}''$
.00000000	.00000000	.00000000	.76079199+000	.00000000	.00000000	.18787580+000
.20000000+000	.14771489-001	.14549426+000	.69417938+000	.35700396-002	.34764069-001	.15975124+000
.39999999+000	.57311409-001	.27769694+000	.62794746+000	.13532797-001	.63937904-001	.13202890+000
.59999999+000	.12497204+000	.39672970+000	.56256486+000	.28778944-001	.87620312-001	.10493765+000
.79999999+000	.21513990+000	.50281554+000	.49857398+000	.48226083-001	.10598271+000	.78893030-001
.99999999+000	.32525735+000	.59629192+000	.43657354+000	.70833732-001	.11927330+000	.54265019-001
.12000000+001	.45284648+000	.67751967+000	.37719383+000	.95618867-001	.12781838+000	.31501194-001
.14000000+001	.59553420+000	.74738631+000	.32106577+000	.12167135+000	.13201981+000	.13906238-001
.16000000+001	.75107740+000	.80630267+000	.26878566+000	.14816846+000	.13234823+000	-.71907386-002
.18000000+001	.91738661+000	.85519232+000	.22087815+000	.17438755+000	.12933163+000	-.22506993-001
.20000000+001	.10925469+001	.89497361+000	.17776106+000	.19971603+000	.12353958+000	-.34916538-001
.21999999+001	.12748346+001	.92663522+000	.13971574+000	.22365780+000	.11556384+000	-.44345524-001
.24000000+001	.14627283+001	.95120669+000	.10686652+000	.24583551+000	.10599657+000	-.50850270-001
.25999999+001	.16549139+001	.96972584+000	.79171967-001	.26598843+000	.95407870-001	-.54596407-001
.28000000+001	.18502828+001	.98320593+000	.56429402-001	.28396581+000	.84324341-001	-.55950427-001
.30000000+001	.20479243+001	.99260490+000	.38292414-001	.29971633+000	.73210740-001	-.54960724-001
.32000000+001	.22471114+001	.99879933+000	.24299303-001	.31327422+000	.62456058-001	-.52351816-001
.33999999+001	.24472824+001	.10025649+001	.13909121-001	.32474320+000	.52365207-001	-.48394897-001
.36000000+001	.26480199+001	.10045644+001	.65409932-002	.33427931+000	.43156692-001	-.43574050-001
.37999999+001	.28490271+001	.10053438+001	.16122949-002	.34207389+000	.34965988-001	-.38279433-001
.39999999+001	.30501051+001	.10053351+001	-.14281733-002	.34833774+000	.27853755-001	-.32946065-001
.41999999+001	.32511306+001	.10048653+001	-.30747933-002	.35328724+000	.21417591-001	-.27559854-001
.43999999+001	.34520364+001	.10041698+001	-.37488775-002	.35713314+000	.16005809-001	-.22631328-001
.45999999+001	.36527942+001	.10034077+001	-.37915425-002	.36007212+000	.12731736-001	-.18206484-001
.47999999+001	.38534017+001	.10026777+001	-.34645480-002	.36228116+000	.94472470-002	-.14343358-001
.49999999+001	.40538711+001	.10020337+001	-.29571939-002	.36391447+000	.69545521-002	-.11002471-001
.51999999+001	.42542225+001	.10014982+001	-.23970786-002	.36510256+000	.50156852-002	-.83992310-002
.54000000+001	.44544778+001	.10010731+001	-.18625998-002	.36595290+000	.35594503-002	-.62465620-002
.56000000+001	.46546585+001	.10007486+001	-.13954572-002	.36655182+000	.24459360-002	-.45604918-002
.57999999+001	.48547830+001	.10005093+001	-.10119194-002	.36696700+000	.17089010-002	-.32697104-002
.59999999+001	.50548668+001	.10003383+001	-.71214965-003	.36725032+000	.11564513-002	-.23029599-002
.61999999+001	.52549218+001	.10002195+001	-.48734112-003	.36744066+000	.77054875-003	-.15940034-002
.63999999+001	.54549571+001	.10001392+001	-.32475608-003	.36756658+000	.50557891-003	-.10845747-002
.65999999+001	.56549793+001	.10000863+001	-.21097064-003	.36764861+000	.32570534-003	-.72566176-003
.67999999+001	.58549929+001	.10000523+001	-.13372115-003	.36770125+000	.20794465-003	-.47758006-003
.69999999+001	.60550011+001	.10000311+001	-.82753779-004	.36773453+000	.13037254-003	-.30925985-003
.71999999+001	.62550059+001	.10000180+001	-.50029309-004	.36775524+000	.80510796-004	-.19709732-003
.74000000+001	.64550087+001	.10000102+001	-.29560166-004	.36776794+000	.48362324-004	-.12365963-003
.75999999+001	.66550102+001	.10000057+001	-.17076544-004	.36777562+000	.29310481-004	-.76392279-004
.77999999+001	.68550111+001	.10000031+001	-.96482050-005	.36778017+000	.17255479-004	-.46472590-004
.79999999+001	.70550116+001	.10000016+001	-.53330588-005	.36778283+000	.99733617-005	-.27839597-004
.82000000+001	.72550118+001	.10000008+001	-.28848230-005	.36778436+000	.56418830-005	-.16414666-004
.84000000+001	.74550119+001	.10000004+001	-.15276538-005	.36778521+000	.31060673-005	-.95263173-005
.86000000+001	.76550120+001	.10000002+001	-.79232499-006	.36778567+000	.16453537-005	-.54297671-005
.88000000+001	.78550120+001	.10000001+001	-.40281331-006	.36778591+000	.82197299-006	-.30310652-005
.90000000+001	.80550120+001	.10000000+001	-.20104157-006	.36778602+000	.36685813-006	-.16470511-005
.92000000+001	.82550120+001	.10000000+001	-.98805980-007	.36778607+000	.12361295-006	-.86004399-006
.94000000+001	.84550120+001	.99999999+000	-.48124899-007	.36778608+000	-.34694469-017	-.41997164-006

TABLE III CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	$\tilde{F}_{21}$	$\tilde{F}_{21}'$	$\tilde{F}_{21}''$	$\tilde{F}_{22}$	$\tilde{F}_{22}'$	$\tilde{F}_{22}''$
.00000000	.00000000	.00000000	.49809172+000	.00000000	.00000000	-.14457511-001
.20000000+000	.99613528-002	.99606525-001	.49785966+000	-.28910427-003	-.28903910-002	-.14436054-001
.39999999+000	.39832614-001	.19905431+000	.49628505+000	-.11552581-002	-.57665867-002	-.14297556-001
.59999999+000	.89546456-001	.29794419+000	.49206720+000	-.25925867-002	-.85948811-002	-.13941678-001
.79999999+000	.15893002+000	.39562219+000	.48396863+000	-.45865796-002	-.11323228-001	-.13286132-001
.99999999+000	.24765569+000	.49119875+000	.47088407+000	-.71108174-002	-.13885357-001	-.12271906-001
.12000000+001	.35519709+000	.58358377+000	.45192962+000	-.10124630-001	-.16206000-001	-.10868966-001
.14000000+001	.48079417+000	.67154078+000	.42654183+000	-.13571912-001	-.18207205-001	-.9081968-002
.16000000+001	.62343089+000	.75376054+000	.39457251+000	-.17381289-001	-.19815452-001	-.69492503-002
.18000000+001	.78182963+000	.82895251+000	.35636163+000	-.21467739-001	-.20959020-001	-.45500773-002
.20000000+001	.95446481+000	.89594545+000	.31276987+000	-.25735661-001	-.21524859-001	-.19923048-002
.21999999+001	.11395973+001	.95379139+000	.26515599+000	-.30083182-001	-.21764103-001	.59272007-003
.24000000+001	.13353285+001	.10018571+001	.21529089+000	-.34407375-001	-.21395395-001	.30635651-002
.25999999+001	.15396706+001	.10398933+001	.16521178+000	-.38609866-001	-.20555448-001	.52655246-002
.28000000+001	.17506275+001	.10680687+001	.11703129+000	-.42602248-001	-.19306592-001	.71354799-002
.30000000+001	.19662786+001	.10869650+001	.72727683-001	-.46310727-001	-.17731546-001	.85344666-002
.32000000+001	.21848574+001	.10975292+001	.33947552-001	-.49679494-001	-.15926074-001	.94359067-002
.33999999+001	.24048164+001	.11009910+001	.18522587-002	-.52672495-001	-.13990547-001	.98382498-002
.36000000+001	.26248739+001	.10987563+001	-.22968910-001	-.55273507-001	-.12021563-001	.97798302-002
.37999999+001	.28440370+001	.10922901+001	-.40508304-001	-.57484632-001	-.10104700-001	.93308352-002
.39999999+001	.30616024+001	.10830053+001	-.51275445-001	-.59323523-001	-.83092303-002	.85821062-002
.41999999+001	.32771363+001	.10721709+001	-.56182473-001	-.60819798-001	-.66852188-002	.76328550-002
.43999999+001	.34904386+001	.10608462+001	-.56383399-001	-.62011105-001	-.52530127-002	.65793280-002
.45999999+001	.37014971+001	.10498477+001	-.53128906-001	-.62939302-001	-.40547748-002	.55058922-002
.47999999+001	.39104379+001	.10397443+001	-.47624729-001	-.63647103-001	-.30574829-002	.44793737-002
.49999999+001	.41174776+001	.10308767+001	-.40930097-001	-.64175413-001	-.22567230-002	.3546734B-002
.51999999+001	.43228813+001	.10233944+001	-.33895886-001	-.64561446-001	-.16306496-002	.27356224-002
.54000000+001	.45269281+001	.10172992+001	-.27142041-001	-.64837610-001	-.11536141-002	.20569747-002
.56000000+001	.47298870+001	.10124919+001	-.21067038-001	-.65031059-001	-.79914327-003	.15087776-002
.57999999+001	.49320001+001	.10088129+001	-.15879208-001	-.65163758-001	-.54212095-003	.10901439-002
.59999999+001	.51334750+001	.10060767+001	-.11639392-001	-.65252905-001	-.36017588-003	.75509338-003
.61999999+001	.53344812+001	.10040966+001	-.83059149-002	-.65311563-001	-.23437710-003	.51565169-003
.63999999+001	.55351526+001	.10027008+001	-.57754216-002	-.65349369-001	-.14939237-003	.34411153-003
.65999999+001	.57355906+001	.10017417+001	-.39158903-002	-.65373238-001	-.93278087-004	.22447043-003
.67999999+001	.59358703+001	.10010988+001	-.25905065-002	-.65388001-001	-.57954195-004	.14316907-003
.69999999+001	.61360449+001	.10006783+001	-.16728629-002	-.65396946-001	-.34187044-004	.89303418-004
.71999999+001	.63361517+001	.10004098+001	-.10549650-002	-.65402256-001	-.20067665-004	.54488141-004
.74000000+001	.65362156+001	.10002422+001	-.64993735-003	-.65405343-001	-.11538878-004	.32525705-004
.75999999+001	.67362530+001	.10001401+001	-.39128440-003	-.65407102-001	-.64980970-005	.18998053-004
.77999999+001	.69362744+001	.10000792+001	-.23025830-003	-.65408083-001	-.35826141-005	.10859461-004
.79999999+001	.71362863+001	.10000438+001	-.13247660-003	-.65408619-001	-.19322461-005	.60754269-005
.82000000+001	.73362929+001	.10000236+001	-.74533476-004	-.65408905-001	-.10177995-005	.33270669-005
.84000000+001	.75362964+001	.10000123+001	-.41013680-004	-.65409054-001	-.52179279-006	.17836288-005
.86000000+001	.77362982+001	.10000062+001	-.22075970-004	-.65409129-001	-.25439732-006	.93614557-006
.88000000+001	.79362991+001	.10000030+001	-.11626376-004	-.65409165-001	-.12144913-006	.48107439-006
.90000000+001	.81362995+001	.10000013+001	-.59909794-005	-.65409182-001	-.51728093-007	.24207048-006
.92000000+001	.83362997+001	.10000004+001	-.30209868-005	-.65409188-001	-.16969639-007	.11927793-006
.94000000+001	.85362997+001	.99999999+000	-.14908762-005	-.65409190-001	.54210108-010	.57556255-007

TABLE III CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	$\tilde{F}_{23}$	$\tilde{F}_{23}'$	$\tilde{F}_{23}''$
.00000000	.00000000	.00000000	-.87215013-001
.20000000+000	-.17440850-002	-.17437780-001	-.87113768-001
.39999999+000	-.69708340-002	-.34807814-001	-.86448444-001
.59999999+000	-.15651922-001	-.51945250-001	-.84706465-001
.79999999+000	-.27716151-001	-.68588150-001	-.81433684-001
.99999999+000	-.43031384-001	-.84391970-001	-.76263741-001
.12000000+001	-.61390004-001	-.98950592-001	-.68953334-001
.14000000+001	-.82499309-001	-.11182454+000	-.59417843-001
.16000000+001	-.10597822+000	-.12257581+000	-.47760405-001
.18000000+001	-.13136146+000	-.13080719+000	-.34285979-001
.20000000+001	-.15811177+000	-.13620271+000	-.19500787-001
.21999999+001	-.18563996+000	-.13856442+000	-.40719852-002
.24000000+001	-.21333149+000	-.13784071+000	.11217526-001
.25999999+001	-.24057751+000	-.13414137+000	.25549307-001
.28000000+001	-.26680734+000	-.12773643+000	.38154047-001
.30000000+001	-.29151893+000	-.11903780+000	.48334918-001
.32000000+001	-.31430409+000	-.10856572+000	.55835203-001
.33999999+001	-.33486588+000	-.96904048-001	.60279201-001
.36000000+001	-.35302634+000	-.84650747-001	.61780281-001
.37999999+001	-.36872451+000	-.72370001-001	.60616273-001
.39999999+001	-.38200542+000	-.60552071-001	.57238357-001
.41999999+001	-.39300233+000	-.49585172-001	.52203387-001
.43999999+001	-.40191463+000	-.39741393-001	.46105235-001
.45999999+001	-.40898437+000	-.31176289-001	.39505750-001
.47999999+001	-.41447391+000	-.23939877-001	.32890834-001
.49999999+001	-.41864660+000	-.17995539-001	.26638136-001
.51999999+001	-.42175167+000	-.13242939-001	.21006863-001
.54000000+001	-.42401389+000	-.95414026-002	.16143194-001
.56000000+001	-.42562764+000	-.67310033-002	.12096922-001
.57999999+001	-.42675486+000	-.46496184-002	.88442303-002
.59999999+001	-.42752591+000	-.31452347-002	.63117781-002
.61999999+001	-.42804242+000	-.20835929-002	.43987318-002
.63999999+001	-.42838129+000	-.13518216-002	.29945125-002
.65999999+001	-.42859904+000	-.85899597-003	.19921598-002
.67999999+001	-.42873608+000	-.53461459-003	.12953707-002
.69999999+001	-.42882056+000	-.32589097-003	.82347770-003
.71999999+001	-.42887157+000	-.19456958-003	.51190194-003
.74000000+001	-.42890174+000	-.11376594-003	.31122735-003
.75999999+001	-.42891921+000	-.65132545-004	.18509503-003
.77999999+001	-.42892911+000	-.36496809-004	.10759614-003
.79999999+001	-.42893461+000	-.19999457-004	.61312587-004
.82000000+001	-.42893759+000	-.10699003-004	.34158074-004
.84000000+001	-.42893917+000	-.55677237-005	.18624151-004
.86000000+001	-.42893997+000	-.27968177-005	.99389359-005
.88000000+001	-.42894037+000	-.13321763-005	.51918322-005
.90000000+001	-.42894055+000	-.57431518-006	.26549269-005
.92000000+001	-.42894062+000	-.19040542-006	.13291273-005
.94000000+001	-.42894064+000	.21684043-018	.65146482-006

TABLE III CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 0.72

LAMBDA	$\tilde{T}_{21}$	$\tilde{T}_{21}'$	$\tilde{T}_{22}$	$\tilde{T}_{22}'$	$\tilde{T}_{23}$	$\tilde{T}_{23}'$
.00000000	-.16866723+001	.00000000	-.24447902-002	.00000000	-.50413085-002	.00000000
.20000000+000	-.16771471+001	.95229668-001	-.21683830-002	.27624983-002	-.33737476-002	.16657832-001
.39999999+000	-.16486112+001	.18997137+000	-.13419143-002	.54915094-002	.16153185-002	.33169382-001
.59999999+000	-.16012695+001	.28302518+000	.20891246-004	.81092436-002	.98569580-002	.49107720-001
.79999999+000	-.15356414+001	.37245479+000	.18865715-002	.10497905-001	.21179926-001	.63903149-001
.99999999+000	-.14526996+001	.45568858+000	.41951463-002	.12512651-001	.35270845-001	.76644963-001
.12000000+001	-.13539803+001	.52970015+000	.68563837-002	.13999083-001	.51547482-001	.86570897-001
.14000000+001	-.12416489+001	.59127638+000	.97499717-002	.14814583-001	.69650654-001	.92773371-001
.16000000+001	-.11185038+001	.63736175+000	.12730171-001	.14851306-001	.88459459-001	.94524364-001
.18000000+001	-.98790646+000	.66544559+000	.15634956-001	.14057381-001	.10713203+000	.91362591-001
.20000000+001	-.85363444+000	.67393776+000	.18298866-001	.12452200-001	.12467016+000	.83200655-001
.21999999+001	-.71966537+000	.66246645+000	.20568009-001	.10132001-001	.14010129+000	.70388466-001
.24000000+001	-.58991495+000	.63203437+000	.22314995-001	.72635015-002	.15256724+000	.53714293-001
.25999999+001	-.46796161+000	.58499050+000	.23451404-001	.40657653-002	.16140620+000	.34336198-001
.28000000+001	-.35679618+000	.52481021+000	.23935664-001	.78324993-003	.16621451+000	.13652211-001
.30000000+001	-.25863230+000	.45571736+000	.23775077-001	-.23448648-002	.16687823+000	-.68683159-002
.32000000+001	-.17480262+000	.38221663+000	.23021836-001	-.51131110-002	.16356972+000	-.25859697-001
.33999999+001	-.10575056+000	.30862150+000	.21764023-001	-.73707476-002	.15471132+000	-.42208753-001
.36000000+001	-.51110009-001	.23865708+000	.20113425-001	-.90322783-002	.14091410+000	-.55152769-001
.37999999+001	-.98521532-002	.17519303+000	.18192353-001	-.10077075-001	.13490311+000	-.64315689-001
.39999999+001	.19529214-001	.12012669+000	.16121472-001	-.10540088-001	.12144133+000	-.69686290-001
.41999999+001	.38823309-001	.74404090-001	.14010108-001	-.10497056-001	.10726266+000	-.71553149-001
.43999999+001	.49923130-001	.38143958-001	.11949743-001	-.10047901-001	.93020582-001	-.70416326-001
.45999999+001	.54677686-001	.10820912-001	.10010765-001	-.93013399-002	.79255185-001	-.66898815-001
.47999999+001	.54783351-001	-.85326511-002	.82419914-002	-.83626124-002	.66377874-001	-.61644017-001
.49999999+001	.51714810-001	-.21136412-001	.66722713-002	-.73250609-002	.54570878-001	-.55291246-001
.51999999+001	.46691255-001	-.28302002-001	.53133987-002	-.62654127-002	.44297607-001	-.48391709-001
.54000000+001	.40670879-001	-.31310600-001	.41636430-002	-.52421130-002	.35319862-001	-.41403549-001
.56000000+001	.34366016-001	-.31328559-001	.32113810-002	-.42958694-002	.27718410-001	-.34678529-001
.57999999+001	.28271664-001	-.29357051-001	.24384671-002	-.34516088-002	.21414184-001	-.28464344-001
.59999999+001	.22701159-001	-.26209746-001	.18231259-002	-.27211841-002	.16288189-001	-.22914750-001
.61999999+001	.17824076-001	-.22511928-001	.13422722-002	-.21063354-002	.12198369-001	-.18104291-001
.63999999+001	.13702677-001	-.18714724-001	.97324303-003	-.16015615-002	.99952917-002	-.14045022-001
.65999999+001	.10324501-001	-.15118693-001	.69498242-003	-.11966823-002	.65329563-002	-.10703302-001
.67999999+001	.76297053-002	-.11901958-001	.48875690-003	-.87897262-003	.46713570-002	-.80152252-002
.69999999+001	.55326476-002	-.91490624-002	.33849021-003	-.63482164-003	.32886725-002	-.58998428-002
.71999999+001	.39378760-002	-.68777849-002	.23081348-003	-.45092939-003	.22790738-002	-.42697012-002
.74000000+001	.27510968-002	-.50622345-002	.15491850-003	-.31508815-003	.15542021-002	-.30366301-002
.75999999+001	.18859781-002	-.36513813-002	.10229053-003	-.21661925-003	.10423493-002	-.21259670-002
.77999999+001	.12677141-002	-.25829365-002	.66381626-004	-.14654428-003	.68582057-003	-.14645893-002
.79999999+001	.83424865-003	-.17929698-002	.42269720-004	-.97567493-004	.44387114-003	-.99221310-003
.82000000+001	.53594759-003	-.12219421-002	.26334477-004	-.63937631-004	.28051833-003	-.66142866-003
.84000000+001	.33435599-003	-.81795078-003	.15967986-004	-.41244837-004	.17243492-003	-.43390971-003
.86000000+001	.20051981-003	-.53796635-003	.93291193-005	-.26192925-004	.10205318-003	-.28015505-003
.88000000+001	.11320272-003	-.34774802-003	.51432676-005	-.16377090-004	.56943312-004	-.17804117-003
.90000000+001	.57204981-004	-.22098760-003	.25446872-005	-.10082328-004	.28483485-004	-.11137861-003
.92000000+001	.21895462-004	-.13808995-003	.95620498-006	-.61120402-005	.10807782-004	-.68592366-004
.94000000+001	.00000000	-.84865680-004	.00000000	-.36487156-005	.00000000	-.41568444-004

TABLE IIII.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	$\tilde{F}_1$	$\tilde{F}_1'$	$\tilde{F}_1''$	$\tilde{T}_{11}$	$\tilde{T}_{11}'$
.00000000	.00000000	.00000000	.33205733+000	.99557433+000	.00000000
.20000000+000	.66409995-002	.66407790-001	.33198383+000	.99116441+000	-.44091252-001
.39999999+000	.26559883-001	.13276415+000	.33146983+000	.97794909+000	-.88003951-001
.59999999+000	.59734636-001	.19893724+000	.33007912+000	.95600369+000	-.13129456+000
.79999999+000	.10610821+000	.26470913+000	.32738926+000	.92552020+000	-.17324305+000
.99999999+000	.16557172+000	.32978002+000	.32300711+000	.88685986+000	-.21288435+000
.12000000+001	.23794871+000	.39377609+000	.31658918+000	.84059693+000	-.24906518+000
.14000000+001	.32298156+000	.45626175+000	.30786538+000	.78754823+000	-.28052981+000
.16000000+001	.42032075+000	.51675677+000	.29666345+000	.72878277+000	-.30603285+000
.18000000+001	.52951802+000	.57475813+000	.28293101+000	.66560672+000	-.32447088+000
.20000000+001	.65002435+000	.62976572+000	.26675154+000	.59952137+000	-.33501816+000
.21999999+001	.78119332+000	.68131036+000	.24835091+000	.53215515+000	-.33724646+000
.24000000+001	.92229010+000	.72898192+000	.22809175+000	.46517504+000	-.33120834+000
.25999999+001	.10725059+001	.77245500+000	.20645462+000	.40018651+000	-.31746599+000
.28000000+001	.12309772+001	.81150961+000	.18400659+000	.33863396+000	-.29705680+000
.30000000+001	.13966082+001	.84604443+000	.16136031+000	.28171430+000	-.27139781+000
.32000000+001	.15690949+001	.87608144+000	.13912805+000	.23031467+000	-.24214351+000
.33999999+001	.17469500+001	.90176120+000	.11787624+000	.18498128+000	-.21102022+000
.36000000+001	.19295251+001	.92332965+000	.98086278-001	.14592159+000	-.17966403+000
.37999999+001	.21160297+001	.94111798+000	.80125918-001	.11303637+000	-.14948652+000
.39999999+001	.23057463+001	.95551821+000	.64234121-001	.85974472-001	-.12158467+000
.41999999+001	.24980396+001	.96695706+000	.50519748-001	.64200484-001	-.96701422-001
.43999999+001	.26923608+001	.97587081+000	.38972611-001	.47065561-001	-.75233057-001
.45999999+001	.28882479+001	.98268348+000	.29483772-001	.33872855-001	-.57272796-001
.47999999+001	.30853206+001	.98778951+000	.21871187-001	.23931835-001	-.42676183-001
.49999999+001	.32832736+001	.99154188+000	.15906799-001	.16598509-001	-.31134530-001
.51999999+001	.34818675+001	.99424552+000	.11341789-001	.11301162-001	-.22244648-001
.54000000+001	.36809190+001	.99615529+000	.79276502-002	.75531395-002	-.15567763-001
.56000000+001	.38802906+001	.99747775+000	.54319580-002	.49552825-002	-.10673805-001
.57999999+001	.40798818+001	.99837548+000	.36484139-002	.31910133-002	-.71707482-002
.59999999+001	.42796208+001	.99897286+000	.24020400-002	.20169158-002	-.47207201-002
.61999999+001	.44794572+001	.99936252+000	.15501708-002	.12511891-002	-.30456893-002
.63999999+001	.46793565+001	.99961168+000	.98061518-003	.76174378-003	-.19258487-002
.65999999+001	.48792957+001	.99976785+000	.60804429-003	.45511191-003	-.11935390-002
.67999999+001	.50792597+001	.99986380+000	.36956258-003	.26682134-003	-.72500448-003
.69999999+001	.52792387+001	.99992159+000	.22016895-003	.15349033-003	-.43166222-003
.71999999+001	.54792267+001	.99995570+000	.12856980-003	.86627458-004	-.25191385-003
.74000000+001	.56792200+001	.99997544+000	.73592973-004	.47960318-004	-.14410146-003
.75999999+001	.58792163+001	.99998664+000	.41290301-004	.26041213-004	-.80797035-004
.77999999+001	.60792143+001	.99999286+000	.22707743-004	.13861720-004	-.44405274-004
.79999999+001	.62792133+001	.99999626+000	.12240919-004	.72279203-005	-.23921403-004
.82000000+001	.64792127+001	.99999807+000	.64679739-005	.36861294-005	-.12631421-004
.84000000+001	.66792125+001	.99999902+000	.33499364-005	.18325498-005	-.65377992-005
.86000000+001	.68792123+001	.99999951+000	.17006657-005	.88166563-006	-.33168425-005
.88000000+001	.70792123+001	.99999975+000	.84628270-006	.40350690-006	-.16494233-005
.90000000+001	.72792122+001	.99999987+000	.41278702-006	.16781497-006	-.80399529-006
.92000000+001	.74792122+001	.99999993+000	.19735615-006	.53935478-007	-.38413949-006
.94000000+001	.76792122+001	.99999996+000	.92488849-007	.00000000	-.17990305-006

TABLE IIII CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	$\tilde{G}_{21}$	$\tilde{G}_{21}'$	$\tilde{G}_{21}''$	$\tilde{G}_{22}$	$\tilde{G}_{22}'$	$\tilde{G}_{22}''$
.00000000	.00000000	.00000000	.76079199+000	.00000000	.00000000	.21277744+000
.20000000+000	.14771489-001	.14549426+000	.69417938+000	.40344539-002	.39240457-001	.17966184+000
.39999999+000	.57311409-001	.27769694+000	.62794746+000	.15256781-001	.71892785-001	.14696824+000
.59999999+000	.12497204+000	.39672970+000	.56256486+000	.32360745-001	.98085904-001	.11514792+000
.79999999+000	.21513990+000	.50281554+000	.49857398+000	.54075132-001	.11804214+000	.84661214-001
.99999999+000	.32525735+000	.59629192+000	.43657354+000	.79182927-001	.13208156+000	.56061921-001
.12000000+001	.45284648+000	.67751967+000	.37719383+000	.10654097+000	.14062239+000	.29773655-001
.14000000+001	.59553420+000	.74738631+000	.32106577+000	.13509924+000	.14417636+000	.62630459-002
.16000000+001	.75107740+000	.80630267+000	.26878566+000	.16391856+000	.14333833+000	-.14090147-001
.18000000+001	.91738661+000	.85519232+000	.22087815+000	.19218578+000	.13876997+000	-.31002329-001
.20000000+001	.10925469+001	.89497361+000	.17775106+000	.21922493+000	.13117792+000	-.44311350-001
.21999999+001	.12748346+001	.92653522+000	.13971574+000	.24450374+000	.12128751+000	-.53994197-001
.24000000+001	.14627283+001	.95120669+000	.10686652+000	.26763449+000	.10981409+000	-.60174033-001
.25999999+001	.16549139+001	.96972584+000	.79171957-001	.28836909+000	.97434122-001	-.63114717-001
.28000000+001	.18502828+001	.98320593+000	.56429402-001	.30658862+000	.84758612-001	-.63202543-001
.30000000+001	.20479243+001	.99260490+000	.38292414-001	.32228798+000	.72311466-001	-.60916832-001
.32000000+001	.22471114+001	.99879933+000	.24299303-001	.33555680+000	.60514472-001	-.56792719-001
.33999999+001	.24472824+001	.10025649+001	.13909121-001	.34655819+000	.49680189-001	-.51380615-001
.36000000+001	.26480199+001	.10045644+001	.65409932-002	.35550689+000	.40012845-001	-.45207284-001
.37999999+001	.28490271+001	.10053438+001	.16122949-002	.36264825+000	.31616494-001	-.38742917-001
.39999999+001	.30501051+001	.10053351+001	-.14281733-002	.36823955+000	.24508873-001	-.32377449-001
.41999999+001	.32511306+001	.10048653+001	-.30747933-002	.37253442+000	.18638919-001	-.26607670-001
.43999999+001	.34520364+001	.10041698+001	-.37488775-002	.37577098+000	.13905799-001	-.21634978-001
.45999999+001	.36527942+001	.10034077+001	-.37915426-002	.37816376+000	.10177431-001	-.17372197-001
.47999999+001	.38534017+001	.10026777+001	-.34645480-002	.37989914+000	.73069573-002	-.13456904-001
.49999999+001	.40538711+001	.10020337+001	-.29571939-002	.38113383+000	.51461274-002	-.92603969-002
.51999999+001	.42542225+001	.10014982+001	-.23970786-002	.38199555+000	.35551670-002	-.67455708-002
.54000000+001	.44544778+001	.10010731+001	-.18625998-002	.38258552+000	.24091582-002	-.48035351-002
.56000000+001	.46546585+001	.10007486+001	-.13954572-002	.38298172+000	.16013531-002	-.33475269-002
.57999999+001	.48547830+001	.10005093+001	-.10119194-002	.38324272+000	.10440377-002	-.22934297-002
.59999999+001	.50548668+001	.10003383+001	-.71214965-003	.38341136+000	.66764138-003	-.15248241-002
.61999999+001	.52549218+001	.10002195+001	-.48734112-003	.38351824+000	.41875377-003	-.99696874-003
.63999999+001	.54549571+001	.10001392+001	-.32475608-003	.38358469+000	.25760383-003	-.63829703-003
.65999999+001	.56549793+001	.10000863+001	-.21097064-003	.38362520+000	.15542189-003	-.40021101-003
.67999999+001	.58549929+001	.10000523+001	-.13372115-003	.38364942+000	.91965256-004	-.24576456-003
.69999999+001	.60550011+001	.10000311+001	-.82753779-004	.38366363+000	.53366306-004	-.14762492-003
.71999999+001	.62550059+001	.10000180+001	-.50029309-004	.38367180+000	.30367707-004	-.87097166-004
.74000000+001	.64550087+001	.10000102+001	-.29560166-004	.38367641+000	.16943688-004	-.50270639-004
.75999999+001	.66550102+001	.10000057+001	-.17076544-004	.38367896+000	.92575393-005	-.28425058-004
.77999999+001	.68550111+001	.10000031+001	-.96482050-005	.38368034+000	.49671796-005	-.15746503-004
.79999999+001	.70550116+001	.10000016+001	-.53330588-005	.38368107+000	.26067871-005	-.85463022-005
.82000000+001	.72550118+001	.10000008+001	-.28848230-005	.38368146+000	.13373966-005	-.45445889-005
.84000000+001	.74550119+001	.10000004+001	-.15276538-005	.38368165+000	.66452051-006	-.23677551-005
.86000000+001	.76550120+001	.10000002+001	-.79232499-006	.38368174+000	.32319080-006	-.12086352-005
.88000000+001	.78550120+001	.10000001+001	-.40281331-006	.38368179+000	.14851190-006	-.60441362-006
.90000000+001	.80550120+001	.10000000+001	-.20104157-006	.38368181+000	.61953609-007	-.29604843-006
.92000000+001	.82550120+001	.10000000+001	-.98805980-007	.38368182+000	.19948455-007	-.14196091-006
.94000000+001	.84550120+001	.99999999+000	-.48124899-007	.38368182+000	-.34694469-017	-.66567909-007

TABLE IIII CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	$\tilde{F}21$	$\tilde{F}21'$	$\tilde{F}21''$	$\tilde{F}22$	$\tilde{F}22'$	$\tilde{F}22''$
.00000000	.00000000	.00000000	.49809172+000	.00000000	.00000000	-.15786867-001
.20000000+000	.99613528-002	.99506525-001	.49785966+000	-.31568590-003	-.31561299-002	-.15762867-001
.39999999+000	.39832614-001	.19905431+000	.49628505+000	-.12614483-002	-.62964015-002	-.15608253-001
.59999999+000	.89546456-001	.29794419+000	.49206720+000	-.28307311-002	-.93832605-002	-.15211782-001
.79999999+000	.15893002+000	.39562219+000	.48396863+000	-.50073733-002	-.12358905-001	-.14483063-001
.99999999+000	.24765569+000	.49119875+000	.47088407+000	-.77620123-002	-.15150005-001	-.13358244-001
.12000000+001	.35519709+000	.58358377+000	.45192962+000	-.11049550-001	-.17573631-001	-.11806130-001
.14000000+001	.48079417+000	.67154078+000	.42654183+000	-.14807924-001	-.19844323-001	-.98333644-002
.16000000+001	.62343089+000	.75376064+000	.39457251+000	-.18958381-001	-.21581994-001	-.74871906-002
.18000000+001	.78182963+000	.82895251+000	.35636163+000	-.23407366-001	-.22820022-001	-.48545068-002
.20000000+001	.95446481+000	.89594545+000	.31276987+000	-.28049975-001	-.23512711-001	-.20563414-002
.21999999+001	.11395973+001	.95379139+000	.26515599+000	-.32774767-001	-.23641169-001	.76255871-003
.24000000+001	.13353285+001	.10018571+001	.21529089+000	-.37469514-001	-.23216732-001	.34486258-002
.25999999+001	.15396706+001	.10398933+001	.16521178+000	-.42027333-001	-.22281327-001	.58487450-002
.28000000+001	.17506275+001	.10690687+001	.11703129+000	-.46352570-001	-.20904538-001	.78423503-002
.30000000+001	.19652786+001	.10869650+001	.72727683-001	-.50365781-001	-.19177699-001	.93378050-002
.32000000+001	.21848574+001	.10975292+001	.33947552-001	-.54007299-001	-.17205759-001	.10289710-001
.33999999+001	.24048164+001	.11009910+001	.18522587-002	-.57239044-001	-.15098055-001	.10699474-001
.36000000+001	.26248739+001	.10987563+001	-.22968910-001	-.60044475-001	-.12959233-001	.10611432-001
.37999999+001	.28440370+001	.10922901+001	-.40508304-001	-.62426850-001	-.10881504-001	.10103796-001
.39999999+001	.30616024+001	.10830053+001	-.51275445-001	-.64406142-001	-.89390510-002	.92762804-002
.41999999+001	.32771363+001	.10721709+001	-.56182473-001	-.66015089-001	-.71851092-002	.82368754-002
.43999999+001	.34904386+001	.10608462+001	-.56383399-001	-.67294917-001	-.56514722-002	.70995885-002
.45999999+001	.37014971+001	.10498477+001	-.53128906-001	-.68291216-001	-.43503798-002	.59250514-002
.47999999+001	.39104379+001	.10397443+001	-.47624729-001	-.69050330-001	-.32777959-002	.48146153-002
.49999994+001	.41174776+001	.10309767+001	-.40930097-001	-.69616508-001	-.24175618-002	.38060514-002
.51999999+001	.43228813+001	.10233944+001	-.33895886-001	-.70029920-001	-.17456805-002	.29343058-002
.54000000+001	.45269281+001	.10172992+001	-.27142041-001	-.70325477-001	-.12342179-002	.22044205-002
.56000000+001	.47298870+001	.10124919+001	-.21067038-001	-.70532385-001	-.85448459-003	.16156384-002
.57999999+001	.49320001+001	.10088129+001	-.15879208-001	-.70674237-001	-.57935373-003	.11558127-002
.59999999+001	.51334750+001	.10060767+001	-.11639392-001	-.70769485-001	-.38472335-003	.80746437-003
.61999999+001	.53344812+001	.10040966+001	-.83059149-002	-.70832127-001	-.25023738-003	.55109032-003
.63999999+001	.55351525+001	.10027008+001	-.57754216-002	-.70872484-001	-.15943507-003	.36756403-003
.65999999+001	.57355906+001	.10017417+001	-.39158903-002	-.70897952-001	-.99510170-004	.23965223-003
.67999999+001	.59358703+001	.10010988+001	-.25905065-002	-.70913699-001	-.60844373-004	.15278436-003
.69999999+001	.61360449+001	.10006783+001	-.16728629-002	-.70923237-001	-.36446097-004	.95262441-004
.71999999+001	.63361517+001	.10004098+001	-.10549650-002	-.70928897-001	-.21387170-004	.58102429-004
.74000000+001	.65362156+001	.10002422+001	-.64993735-003	-.70932187-001	-.12294097-004	.34671352-004
.75999999+001	.67362530+001	.10001401+001	-.39128440-003	-.70934061-001	-.69215672-005	.20244942-004
.77999999+001	.69362744+001	.10000792+001	-.23025830-003	-.70935105-001	-.38151495-005	.11568830-004
.79999999+001	.71362863+001	.10000438+001	-.13247660-003	-.70935676-001	-.20571919-005	.64705470-005
.82000000+001	.73362929+001	.10000236+001	-.74533476-004	-.70935980-001	-.10833847-005	.35425587-005
.84000000+001	.75362964+001	.10000123+001	-.41013680-004	-.70936139-001	-.55530791-006	.18987106-005
.86000000+001	.77362982+001	.10000062+001	-.22076970-004	-.70936219-001	-.27494546-006	.99632991-006
.88000000+001	.79362991+001	.10000030+001	-.11625376-004	-.70936257-001	-.12920631-006	.51189819-006
.90000000+001	.81362995+001	.10000013+001	-.59909794-005	-.70936275-001	-.55024396-007	.25753145-006
.92000000+001	.83362997+001	.10000004+001	-.30209868-005	-.70936282-001	-.18048891-007	.12687342-006
.94000000+001	.85362997+001	.99999999+000	-.14908762-005	-.70936283-001	.54210108-019	.61211040-007

TABLE IIII CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 1.00

LAMBDA	$\tilde{F}23$	$\tilde{F}23'$	$\tilde{F}23''$
.00000000	.00000000	.00000000	-.87215013-001
.20000000+000	-.17440850-002	-.17437780-001	-.87113768-001
.39999999+000	-.69708340-002	-.34807814-001	-.86448444-001
.59999999+000	-.15651922-001	-.51945250-001	-.84706465-001
.79999999+000	-.27716151-001	-.68588150-001	-.81433684-001
.99999999+000	-.43031384-001	-.84391970-001	-.76263741-001
.12000000+001	-.61390004-001	-.98950592-001	-.68953334-001
.14000000+001	-.82499309-001	-.11182454+000	-.59417843-001
.16000000+001	-.10597822+000	-.12257581+000	-.47760405-001
.18000000+001	-.13136146+000	-.13080719+000	-.34286979-001
.20000000+001	-.15811177+000	-.13620271+000	-.19500787-001
.21999999+001	-.18563996+000	-.13856442+000	-.40719852-002
.24000000+001	-.21333149+000	-.13784071+000	.11217526-001
.25999999+001	-.24057751+000	-.13414137+000	.25549307-001
.28000000+001	-.26680734+000	-.12773643+000	.38154047-001
.30000000+001	-.29151893+000	-.11903780+000	.48394919-001
.32000000+001	-.31430409+000	-.10856572+000	.55835203-001
.33999999+001	-.33486588+000	-.96904048-001	.60279201-001
.36000000+001	-.35302634+000	-.84650747-001	.61780281-001
.37999999+001	-.36872451+000	-.72370001-001	.60615273-001
.39999999+001	-.38200542+000	-.60552071-001	.57238357-001
.41999999+001	-.39300233+000	-.49585172-001	.52203887-001
.43999999+001	-.40191463+000	-.39741393-001	.46105235-001
.45999999+001	-.40898437+000	-.31176289-001	.39565750-001
.47999999+001	-.41447391+000	-.23939877-001	.32890834-001
.49999999+001	-.41864660+000	-.17995539-001	.26638136-001
.51999999+001	-.42175167+000	-.13242939-001	.21006883-001
.54000000+001	-.42401389+000	-.95414028-002	.16143194-001
.56000000+001	-.42562764+000	-.67310033-002	.12095922-001
.57999999+001	-.42675486+000	-.46496184-002	.88442303-002
.59999999+001	-.42752591+000	-.31452347-002	.63117781-002
.61999999+001	-.42804242+000	-.20835929-002	.43937313-002
.63999999+001	-.42838129+000	-.13518216-002	.29946125-002
.65999999+001	-.42859904+000	-.85899597-003	.19921598-002
.67999999+001	-.42873608+000	-.53461459-003	.12953707-002
.69999999+001	-.42882056+000	-.32589097-003	.82347770-003
.71999999+001	-.42887157+000	-.19456958-003	.51190194-003
.74000000+001	-.42890174+000	-.11376584-003	.31122735-003
.75999999+001	-.42891921+000	-.65132545-004	.18589503-003
.77999999+001	-.42892911+000	-.36496809-004	.10759614-003
.79999999+001	-.42893461+000	-.19999457-004	.61312587-004
.82000000+001	-.42893759+000	-.10699003-004	.34159074-004
.84000000+001	-.42893917+000	-.55677237-005	.18624151-004
.86000000+001	-.42893997+000	-.27968177-005	.99389359-005
.88000000+001	-.42894037+000	-.13321763-005	.51918322-005
.90000000+001	-.42894055+000	-.57431516-006	.26549269-005
.92000000+001	-.42894062+000	-.19040542-006	.13291273-005
.94000000+001	-.42894064+000	.21684043-018	.65146482-005

TABLE IIII CON'T.- BOUNDARY LAYER SOLUTIONS WITHOUT HEAT TRANSFER FOR PRANDTL NUMBER OF 1.0

LAMBDA	$\tilde{T}_{21}$	$\tilde{T}_{21}'$	$\tilde{T}_{22}$	$\tilde{T}_{22}'$	$\tilde{T}_{23}$	$\tilde{T}_{23}'$
.00000000	-.19893611+001	.00000000	.26957733-003	.00000000	.11440174-002	.00000000
.20000000+000	-.19761321+001	.13225319+000	.68873841-003	.41887035-002	.34599278-002	.23146314-001
.39999999+000	-.19365110+001	.26359407+000	.19411322-002	.83154966-002	.10385041-001	.46016026-001
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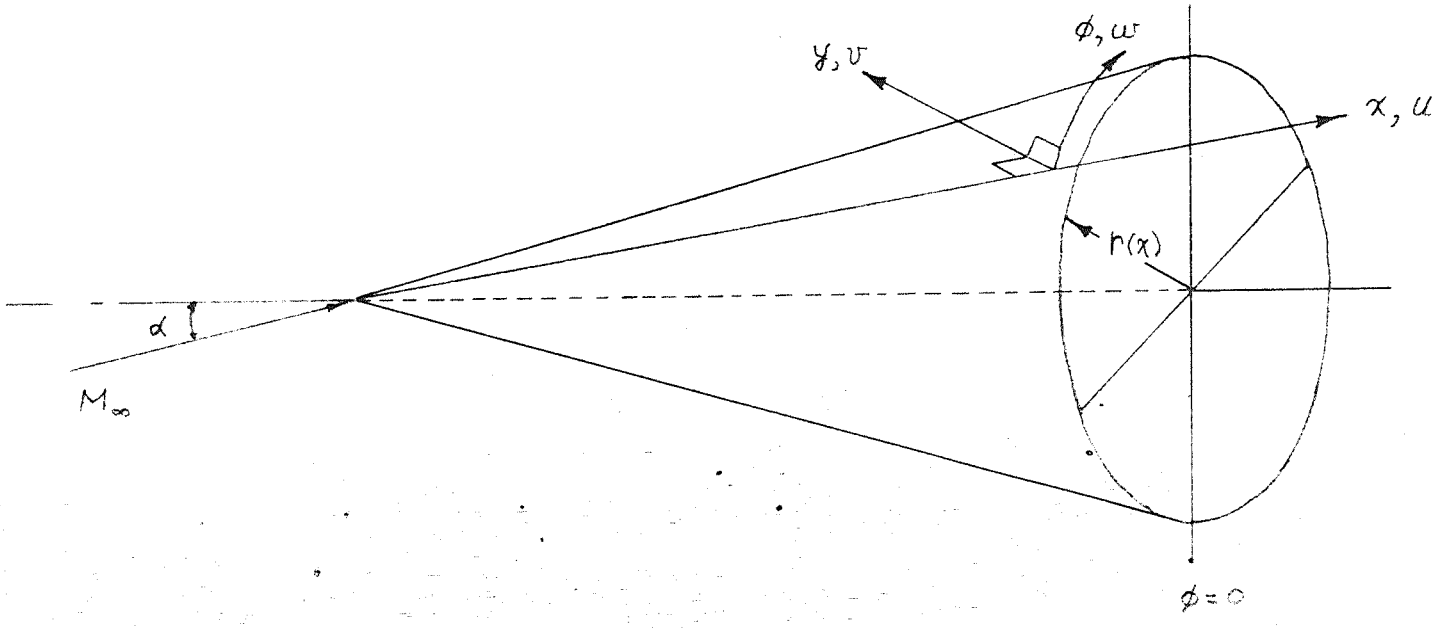


Fig. 1 Coordinate system

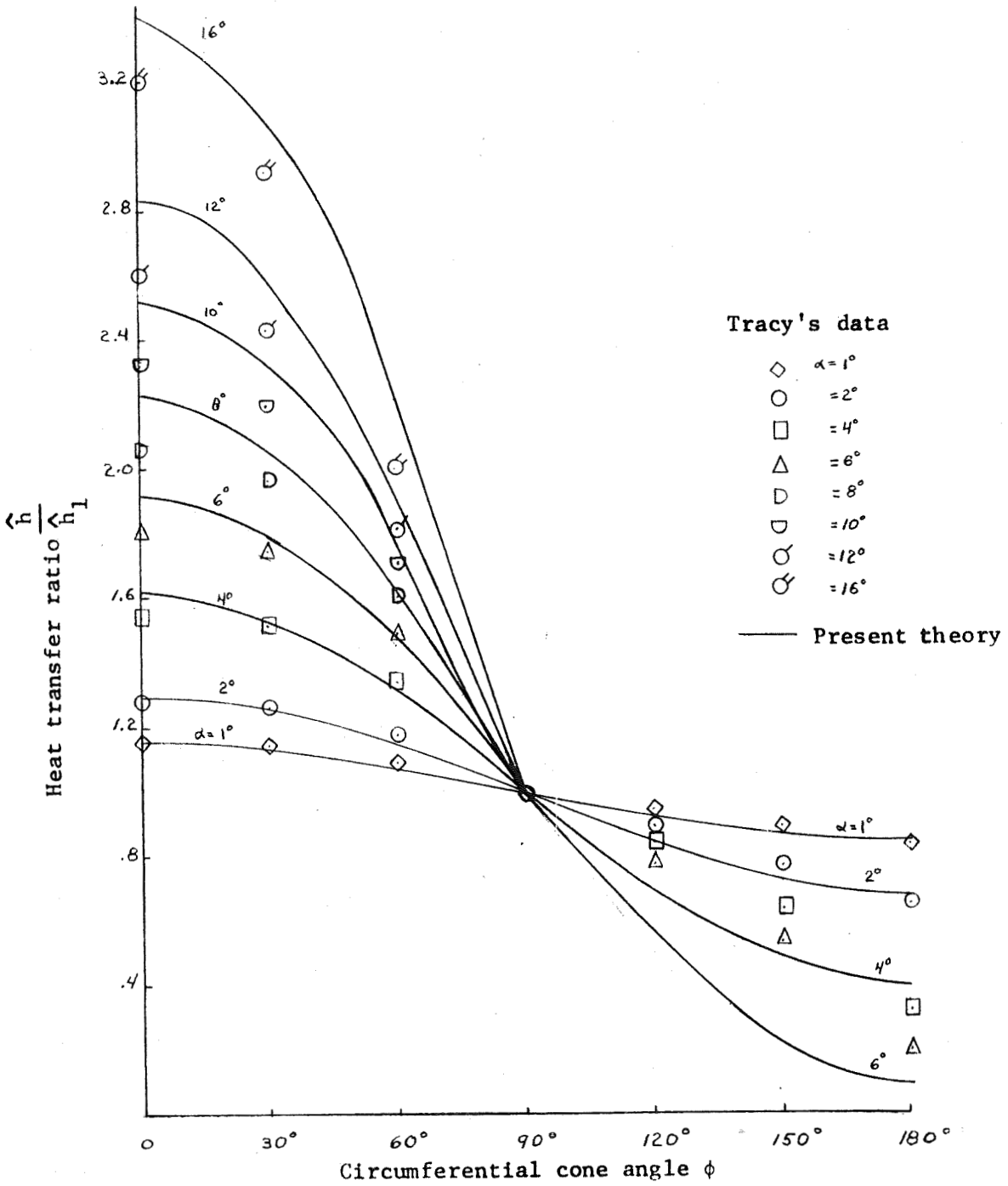


Fig. 2 Heat transfer on 10° cone

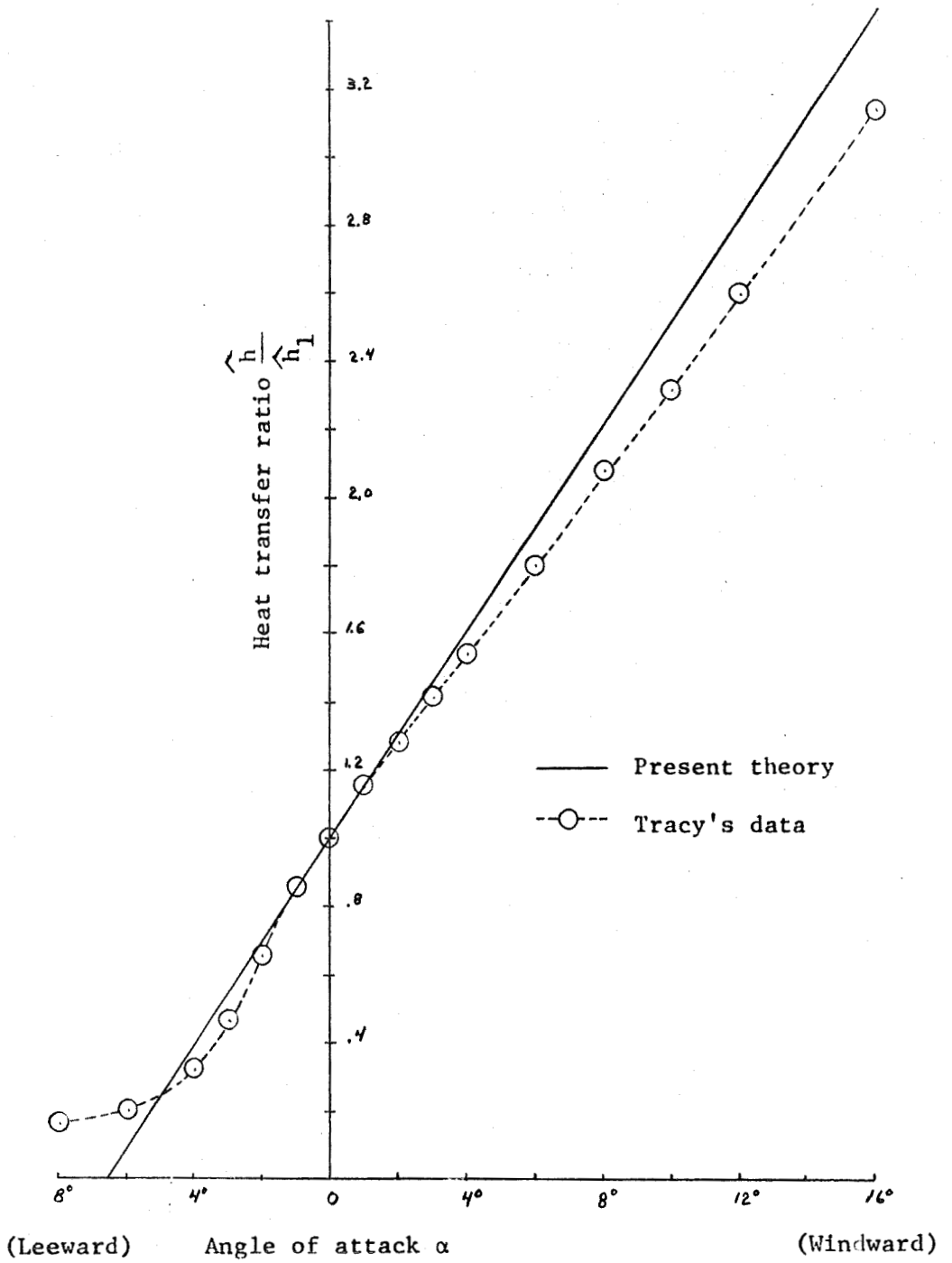
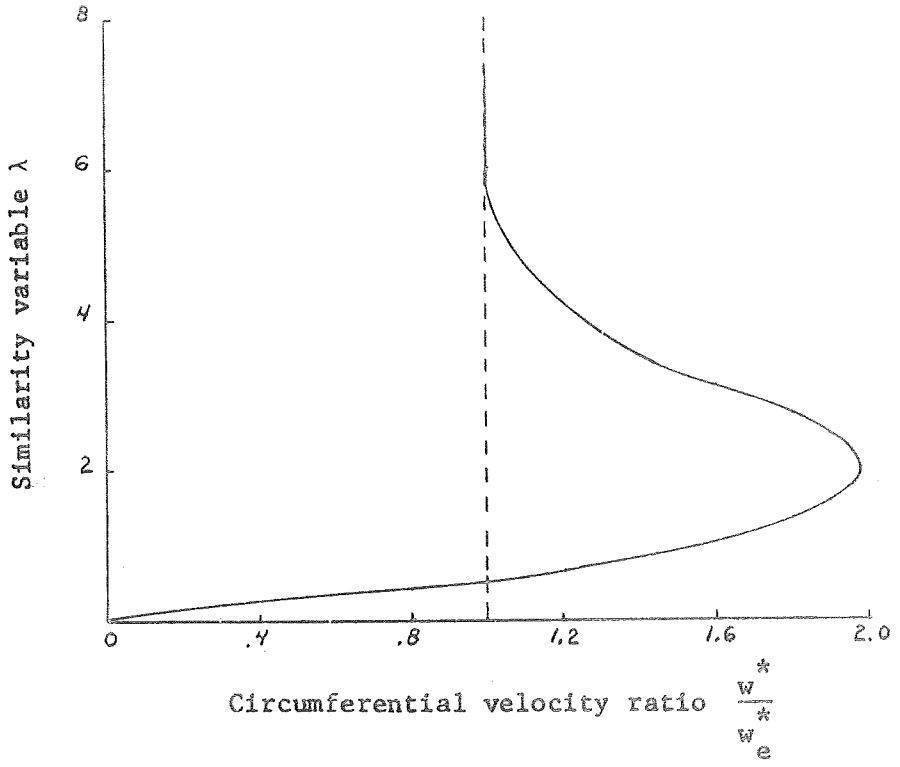


Fig. 3 Heat transfer in the plane of symmetry



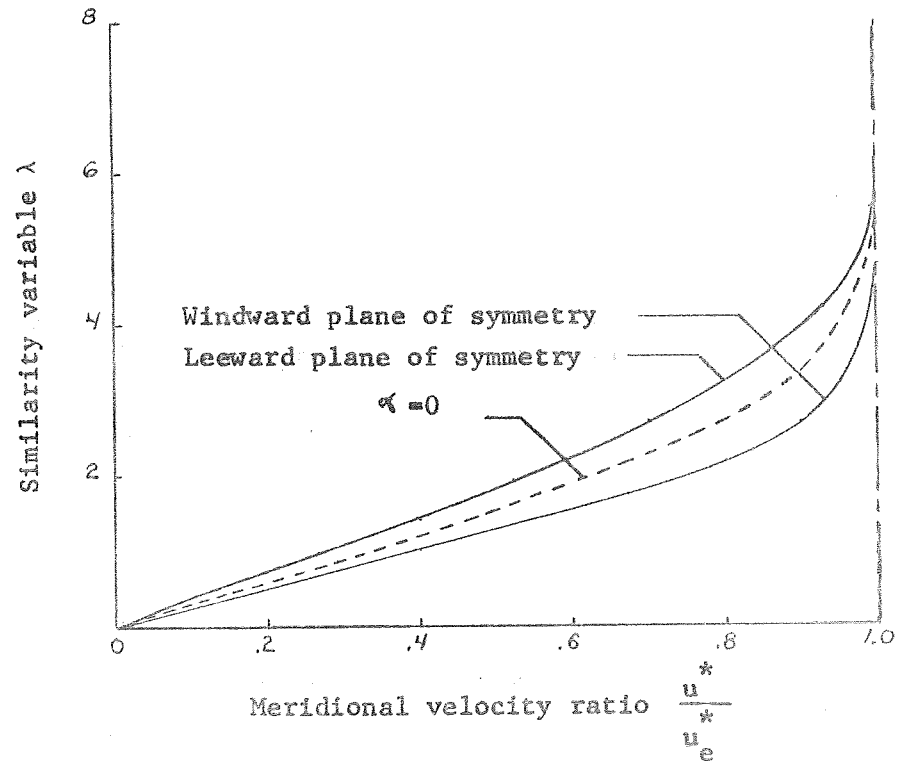
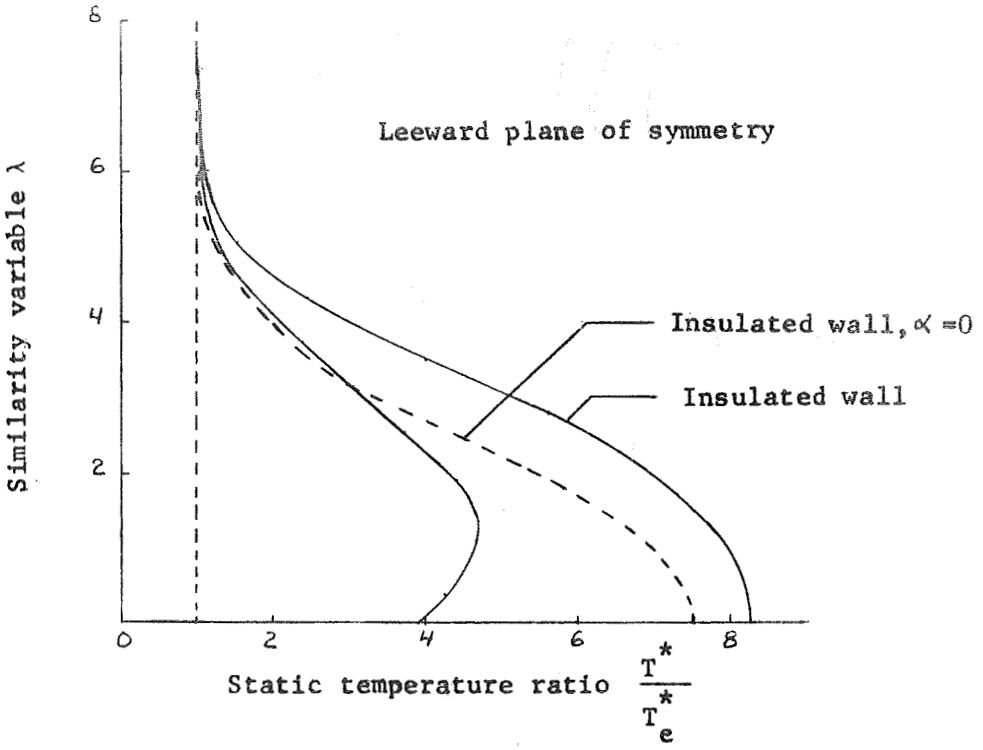


Fig. 4 Velocity profiles on a 10° cone, $\alpha = 2°$



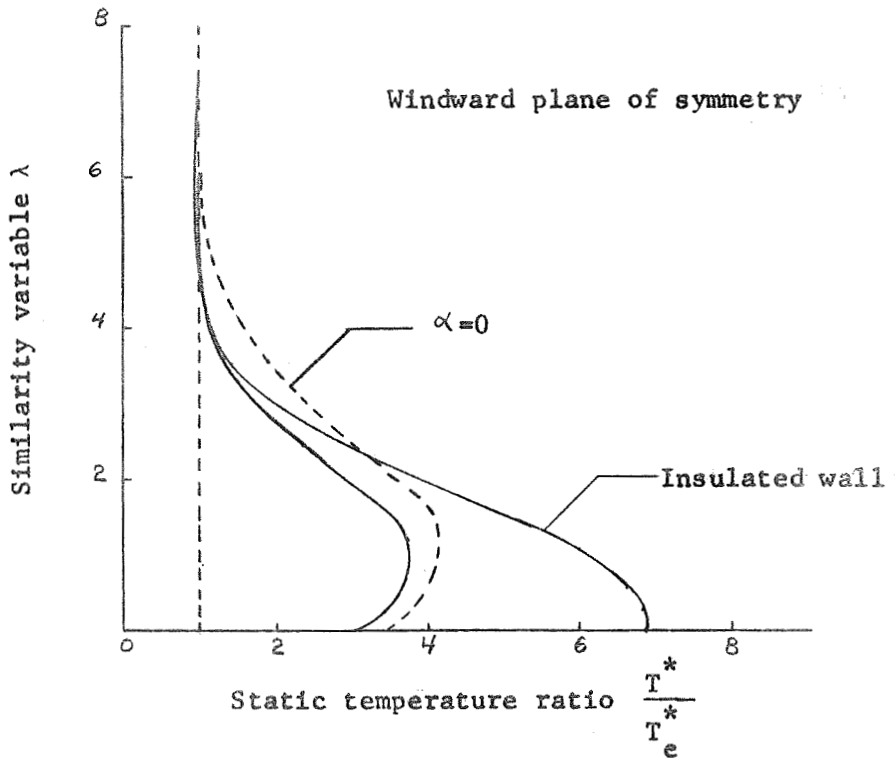


Fig. 5 Temperature profiles in plane of symmetry, $\alpha = 2°$

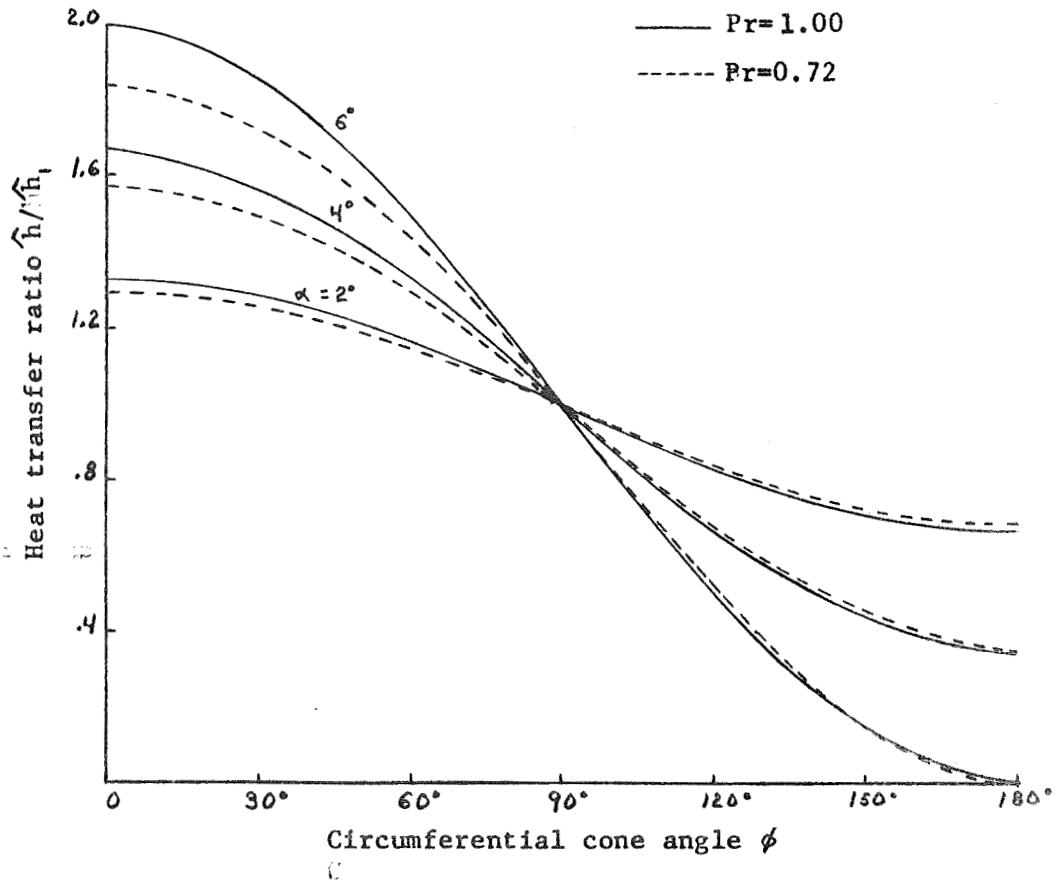


Fig. 6 Heat transfer on a 10° cone for Prandtl numbers of 1.00 and 0.72

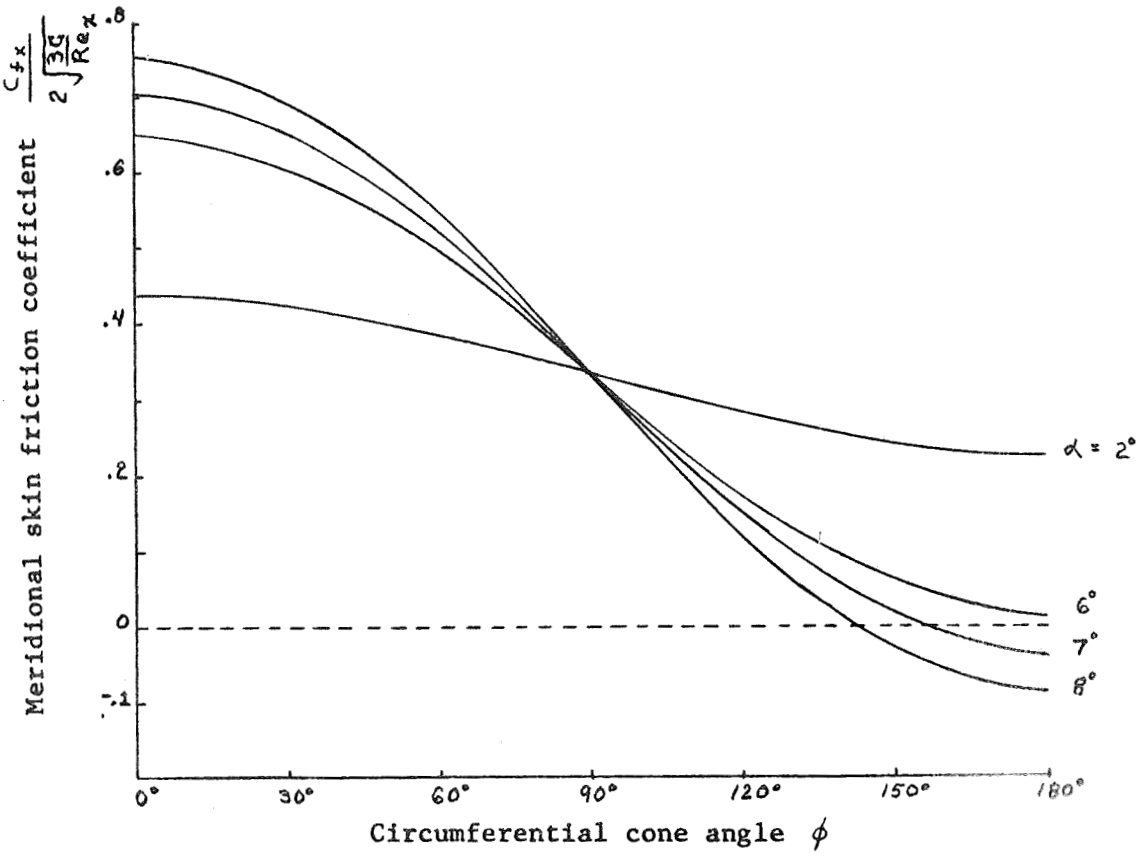


Fig. 7 Meridional skin friction on a 10° cone

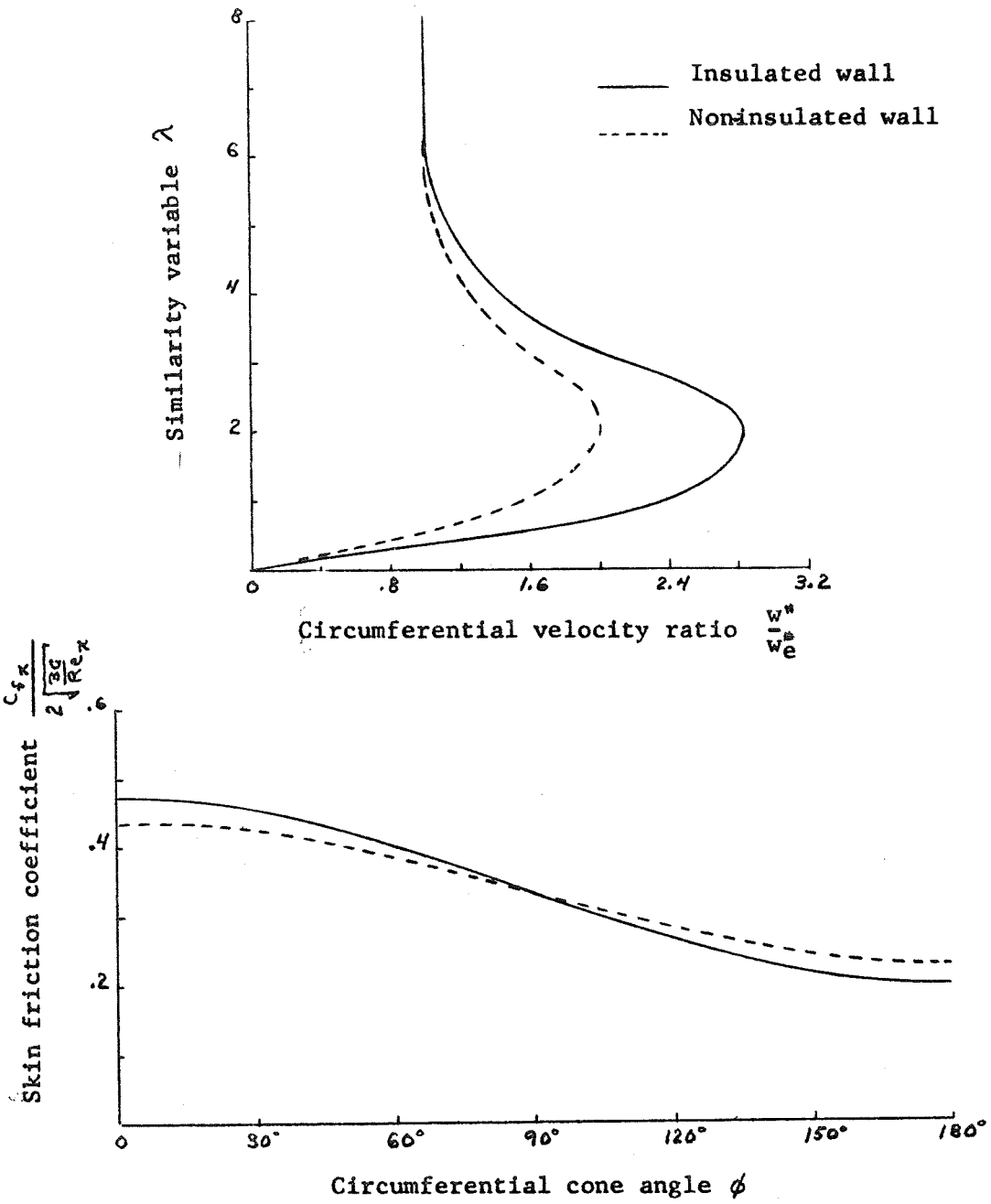


Fig. 8 Velocity and skin friction for insulated and non-insulated walls for Prandtl number of 0.72 and $\alpha = 2°$

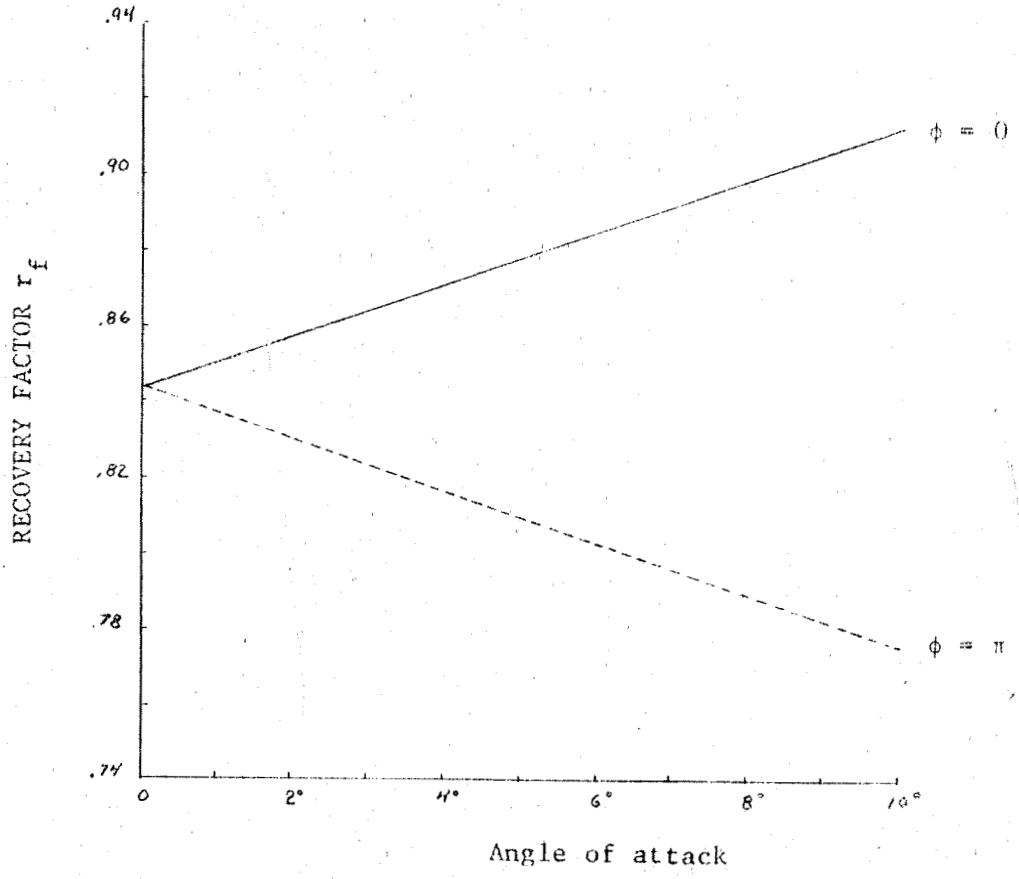


Fig. 9 Recovery factor on a 10° cone for Prandtl number 0.72